MITIGATING GLOBAL CLIMATE CHANGE THROUGH THE ADOPTION OF DEMAND-SIDE TECHNOLOGIES:

Case Studies of the California South Coast and the State of Vermont

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<u>Administration, Technical Guidance, and Publications</u>

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CHAPTER I
OVERVIEW OF RESULTS

A. BACKGROUND AND PURPOSE

Two major studies of U.S. greenhouse gas emissions were released for review in 1991. Both reached essentially the same conclusion: energy conservation measures offer the most cost-effective option for achieving reductions in greenhouse gases resulting from the burning of fossil fuels. In the report "Policy Implications of Greenhouse Warming," the National Academy of Sciences stated that:

"The efficiency of practically every end use of energy can be improved relatively inexpensively . . ."

. . . such as space heating and cooling, lighting, water heating, refrigeration, and cooking. Another study, "Changing by Degrees -- Steps to Reduce Greenhouse Gases," by the U.S. Congress's Office of Technology Assessment (OTA), identified energy conservation to be:

". . . the first logical step for the United States if it wishes to reduce its own CO_2 emissions below present levels over the next 25 years."

These separate but similar findings have prompted increased interest within States and regulatory agencies in policy options aimed at reducing greenhouse gas emissions through energy efficiency improvement using policy vehicles such as encouragement of electric and gas utility Demand-Side Management (DSM) measures. Many such options appear to have positive benefits to virtually all parties, representing the best of all worlds: policies with no losers.

While proceeding with research and policy analysis activities directed at improving energy efficiency appears to be warranted, many smaller States and regulatory agencies lack the experience and staff resources to plan, budget for, and set up such studies, whether fully performed in-house or with contractor assistance. Such organizations have had a need (expressed to the U.S. Environmental Protection Agency [EPA]) for assistance in several areas: (1) simple, publicly available modeling options and guidelines for planning and estimating the resources that should be applied to such studies, (2) defining reasonable scenarios to be investigated, and (3) guidance on selecting from a growing (and rather daunting) array of models and methodologies which are available as products of government-sponsored research, as well as from commercial vendors.

These diverse needs gave impetus to this report, which was commissioned by the South Coast Air Quality Management District (SCAQMD -- the District) in spring 1992. While the project was partly supported by the District, major funding was supplied by the

Global Climate Change Division of EPA, through a grant to the State of California Air Resources Board. The study had several objectives which evolved to the following specific purposes:

- To investigate the state-of-the-art in DSM modeling;

- To outline, to the extent possible, a simple, step-by-step approach to developing technology data, technology selection criteria, and incentive guidelines to be used in such an analysis;

- To develop a DSM analysis tool that would be available in the public domain and could be used by regulatory agencies to analyze the effects of energy conservation measures on energy use and emissions; and

- To perform case studies of two distinct DSM modeling approaches (one using the newly developed model) which demonstrate differences in climate and technique, and investigate the impacts on energy demand and related greenhouse gas emissions.

Two regions, the State of Vermont and the SCAQMD administrative region, were selected as test areas to evaluate modeling techniques and data, with emphasis on the DSM possibilities of current economic technologies with high energy/emissions impacts. The District study area consists of the service areas of Southern California Edison (SCE), the small municipal utilities for Burbank, Glendale, and Pasadena (together called BGP), The Los Angeles Department of Water and Power (LADWP), and Southern California Gas (SCG).

B. SCENARIO DEFINITION AND SECTORAL COVERAGE

The study covered the 20-year period from 1991 to 2011. Each region's current stock of energy-using equipment and building square footage was considered, and the currently mandated State and Federal energy efficiency standards were enforced.

Two "Business-as-Usual" (BAU), or baseline, scenarios were developed to encompass the range of future energy conservation activities without active utility and government DSM policies. These were a "Frozen Efficiency" case, in which the only efficiency changes could come when technologies were replaced, and a "Market Potential" case, in which efficient technologies could compete fairly without incentives.

To investigate the effects of DSM programs, two "action" cases were developed, with increasing levels of utility and/or government financial involvement. These were a "Utility Incentives" case, in which DSM measures are applied to a select group of technologies, and a more aggressive case called "Technology Forcing," in which the list of technologies which were given incentives is expanded, possibly to include general government funding.

The study investigated only the direct efficiency effects of technologies and space conditioning measures in the residential, commercial, and industrial sectors. It *excluded* utility time-of-use pricing efforts or load management incentives such as the installation of utility-controlled switches for air conditioning units. While load management options have come to occupy a substantial allocation fraction of utility DSM budgets, especially in the commercial and industrial sectors (e.g., SCE spent $20 million on load management programs out of a total DSM budget of $106.3 million in 1991), the net energy reductions are normally estimated to be zero for load measures (because the energy is generally offset by higher off-peak use), so they were not considered to be a major source of economical greenhouse gas emissions reductions.

Regional needs for heating and cooling energy requirements are extremely varied and represent the single major element driving the benefits of technologies across the nation. For instance, Table I-1 shows the average household budgets for heating and cooling for prototype residences in major cities near the case study areas.

Table I-1
Space Conditioning Household Energy Usage
(MMBtu/Year)

Conditioning Type	Boston (Used as a proxy for Vermont)	Los Angeles (Centroid for the District)	National Average
Average heating load	192.0	36.5	131.7
Average cooling load	17.9	6.0	47.3

SOURCE: Koomey et al., 1991.

As is evident in the table, which was extrapolated from a U.S. Department of Energy (DOE) Federal region analysis, the heating and cooling budgets for Los Angeles are less than one fourth of the national average, whereas Vermont's heating needs exceed the national average by 46 percent.

C. SUMMARY OF SCAQMD RESULTS

1. *Caveats Related to the SCAQMD Results*

a. *Acceptance Factors*

Market studies for energy efficient devices often find that, for various reasons, including access to information, income level, illiteracy, etc., a percentage of the buying public will not accept an energy saving device, regardless of the price. For instance, a recent study showed that only about 45 percent of those polled would consider accepting compact fluorescent bulbs to replace filament bulbs (Evans, et al., 1992).

To account for such behavior, utilities have used "acceptance" or "willingness" factors in their DSM modeling. For example, Southern California Edison uses a "percent unwilling" factor of 15 percent (85 percent acceptance), and Southern California Gas uses estimates varying from 0.4 to 0.9 for the "customer acceptance" factor. Since (fortunately) the model used for the District had the property of being directly proportional, or "linear" with respect to this factor, a decision was made to use a 100 percent acceptance factor for all scenarios of the study. To find out what the results for the District might have been with an 85 percent acceptance factor, for example, the reported savings could simply be reduced by 15 percent, without re-running the model.

b. Utility Rebate Percentages

As discussed in the next chapter, the "Utility Incentives" scenario was modeled using the *maximum* possible incentive level: 100 percent of the incremental cost differential of the efficient measure. During a review session of the draft report, it was pointed out that the California Public Service Commission has not granted DSM measure rebates to public utilities of over 50 percent, and most tend to be in the 30 percent to 50 percent range. The 100 percent reduction was intended to measure the *upper bound* on total energy and emissions savings potential as calculated by the model, understanding that such a possibility appears to be highly unlikely at the present time.

2. Scenario Savings Increments

Table I-2 shows the major results of the study for the District, taken as a "snapshot" in the year 2011. These results show that the technical potential for electrical energy efficiency savings from a "frozen" baseline condition is 30,200 (106,100 - 75,900) gigawatt hours (GWh) per year, or a 28.5 percent reduction. If basis for measurement is considered to be the midpoint between the two baselines, the reduction is only 22.7 percent. As the table indicates, natural gas measures are less attractive on the basis of pure energy savings. The emissions benefits, however, are more immediate for natural gas than for electricity, mainly because the geographic location and type of electricity generating equipment is scattered and diverse, whereas virtually all of the natural gas impact is at the equipment site.

Table I-3 shows a summary of total costs by sector for the District to achieve potential annual DSM savings in the year 2011. Costs are provided in 1992 dollars and represent the total cost over the entire forecast period. The cost of saved energy (CSE) and the cost of saved power (CSP) are also provided. These are the annualized costs divided by annual savings (in kWh, Therms, or kW). A discount rate of 10 percent was used to annualize the cost for the Market Potential scenario, and a discount rate of 2 percent was used to annualize the cost for the Utility Incentives and Technology Forcing scenarios. More detailed CSE and CSP values by utility, scenario, sector, and end use are provided in Chapter VI. The Utility Incentives and Technology Forcing scenarios include a 20 percent administrative cost added to the incremental cost of each measure. Total costs for the Utility Incentives scenarios are $5.8 billion for the residential sector, $2.5 billion for the commercial sector, and $1.9 billion for the industrial sector. Total costs for the Technology Forcing scenarios are $8.3 billion for the residential sector, $3.3 billion for the commercial sector, and $2.2 billion for the industrial sector.

Perhaps the most surprising finding for the modeling done for the District was the relatively low incremental difference that Technology Forcing makes when compared to the Utility Incentives scenario: over 93 percent of the reductions are achieved with the Utility Incentives, whereas Technology Forcing makes up only an additional 6.4 percent of

Table I-2
DSM Savings Potential for the District[1,2]
Year 2011

Electricity Sales, Gigawatt-hours/year

	Baseline Scenarios			Action Scenarios	
Sector	Frozen Efficiency	Market Potential	Average Baseline	Utility Incentives	Technology Forcing
Residential	28,532	21,917	25,225	16,863	16,719
Commercial	36,517	30,389	33,453	26,529	25,720
Industrial	41,056	37,877	39,467	34,432	33,461
Total	106,105	90,183	98,145	77,824	75,900
Percent Savings from the Average Baseline for Modelled End Uses[3]				20.7	22.7

Peak Load, Megawatts

	Baseline Scenarios			Action Scenarios	
Sector	Frozen Efficiency	Market Potential	Average Baseline	Utility Incentives	Technology Forcing
Residential	9,198	7,855	8,527	6,554	6,519
Commercial	9,285	7,769	8,527	6,814	6,576
Industrial	6,660	6,145	6,403	5,586	5,428
Total	25,143	21,769	23,457	18,954	18,523
Percent Savings from Average Baseline for Modelled End Uses				19.2	21.0

Natural Gas Sales, Million Therms

	Baseline Scenarios			Action Scenarios	
Sector	Frozen Efficiency	Market Potential	Average Baseline	Utility Incentives	Technology Forcing
Residential	2,638	2,528	2,583	2,459	2,363
Commercial	886	830	858	801	797
Industrial	4,097	3,712	3,905	3,322	3,207
Total	7,621	7,070	7,346	6,582	6,367
Percent Savings from Average Baseline for Modelled End Uses				10.4	13.3

NOTES: [1]Includes only the portions of the service areas of SCE, LADWP, BGP, and SCG within the jurisdictional boundaries of the District.

[2]Data sources: SCE, 1992 and SCG, 1992 (see references).

[3]The sales estimates include only the technologies and end uses which were modeled for the study, and located within the District. Several end uses such as consumer electronics were not included in the model. Were these to be included, the percentage reduction results would be significantly lowered, since the base sales level, from which the percentages are calculated, would be increased. The sales data of the table represent approximately 80 percent of total sales of the electric utilities.

Table I-3
Summary of Total Costs by Sector for the District to Achieve Potential Annual DSM Savings in Year 2011
(1992 Dollars)

Residential Sector	Market Potential	Utility Incentives	Technology Forcing
Electric			
Total Cost (MM$)	1,670	4,269	5,041
Total Incentives (MM$)	0	4,154	4,948
CSE ($/kWh)	0.038	0.041	0.042
2011 Savings (GWh)	6,615	11,669	11,813
CSP ($/kW)	172	184	200
2011 Savings (MW)	1,343	2,573	2,678
Natural Gas			
Total Cost (MM$)	279	1,720	3,365
Total Incentives (MM$)	0	1,614	3,316
CSE ($/Therms)	0.40	0.48	0.57
2011 Savings (MMTherms)	88	209	317
Commercial Sector			
Electric			
Total Cost (MM$)	786	2,361	3,111
Total Incentives (MM$)	0	2,280	3,050
CSE ($/kWh)	0.025	0.027	0.032
2011 Savings (GWh)	6,128	9,988	10,797
CSP ($/kW)	123	124	140
2011 Savings (MW)	1,235	2,189	2,439
Natural Gas			
Total Cost (MM$)	38	281	291
Total Incentives (MM$)	0	242	253
CSE ($/Therms)	0.082	0.191	0.198
2011 Savings (MMTherms)	56	85	88
Industrial Sector			
Electric			
Total Cost (MM$)	465	1,142	1,315
2011 Savings (GWh)	3,180	6,624	7,596
2011 Savings (MW)	516	1,074	1,232
Natural Gas			
Total Cost (MM$)	329	731	864
2011 Savings (MMTherms)	397	787	902

NOTES: See Chapter VI for more detail on costs and savings by utility, scenario, sector, and end use.

electrical energy savings. This result is traceable to the apparent fact that the universe of proven technologies that can be justified economically for utility or government subsidies (using a social cost-benefit screening test) and that are not now expected to either be selected through actions of new standards or utility incentives, were found to be rather scarce.

3. Emissions Impacts for the District

The relative magnitude of the DSM-related emissions reductions may be seen in Table I-4, which compares the forecast reductions with a recent inventory estimate for CO_2 and NO_x. As the table shows, the NO_x reductions are relatively minor compared with the CO_2 reductions. This appears to be mainly due to the recently imposed stationary source NO_x regulations in the District, now among the most stringent in the nation.

4. Promising Residential Technologies

The residential sector savings from the most extreme scenario, Technology Forcing, is 11,813 GWh/year using the Frozen Efficiency baseline, which is shown in Table I-2. Figure I-1 shows how this energy savings was developed by end-use sector and the cost in terms of dollars per kilowatt-hour ($/kWh). This curve is the "DSM supply curve" for residential end uses in the District. Figure I-2 shows the percentage savings for the Utility Incentives scenario (which was essentially the same for the Technology Forcing scenario). As these figures indicate, the residential technologies that have most potential for savings are refrigeration (37 percent), lighting (25 percent), and electric hot water (11 percent) -- all savings which may be made at total recovered costs of under $0.04/kWh (well below the avoided costs of new electricity in the District). Space cooling, which has the highest cost of all end uses, shows only 6 percent of the potential savings.

5. Promising Commercial End-Use Categories

Figures I-3 and I-4 show the end-use technology categories that are the most economic sources of electricity DSM savings in the commercial sector. Total savings for these categories were 10,797 GWh/year in 2011 for the Technology Forcing scenario against the Frozen Efficiency baseline. The figures show that commercial lighting has an overwhelming potential for electrical energy savings, representing 72 percent of all commercial savings resulting from the incentives and technologies that were modeled. Next in terms of total commercial savings is space cooling, at 14 percent. Commercial refrigeration technologies effect lower absolute savings (7 percent of the total) but do so at the lowest cost of all the commercial technologies.

6. Industrial Energy Savings

With the unbundling of services in the natural gas industry, the practice of making deliveries for the account of others has grown rapidly, now representing 54 percent of commercial and industrial consumption. (Residential customers do not generally participate in this practice.) The gas utilities refer to such arrangements, in which they operate as carriers only, as "noncore" customers, versus their "core" customers, for which gas utility-owned gas is supplied.

Table I-4
Maximum DSM-Related Emission Reductions

For the District Only		
CO_2 Reductions		
1987 Inventory	**Year 2000**	**Year 2011**
122.4 MMtpy[1]	4.69 MMtpy = 3.8 percent of 1987	9.80 MMtpy = 8.0 percent of 1987
NO_x Reductions		
1989 Inventory	**Year 2000**	**Year 2011**
1,100 tons/day[2] = 401,500 tpy	2,642 tpy = 0.7 percent of 1989	5,519 tpy = 1.4 percent of 1989
For All Sources, Including Out-of-District Burn Sites and Generation		
CO_2 Reductions		
See Note 3.	**Year 2000**	**Year 2011**
	12.6 MMtpy	25.0 MMtpy
NO_x Reductions		
See Note 3.	**Year 2000**	**Year 2011**
	5,031 tpy	9,512 tpy

SOURCE: [1]Piccot et al., 1991.
[2]CARB, 1991.
[3]No inventory was available for all affected out-of-District generation and burn sites.

Figure I-1
Residential Electricity DSM Supply Curve for the California /District Region

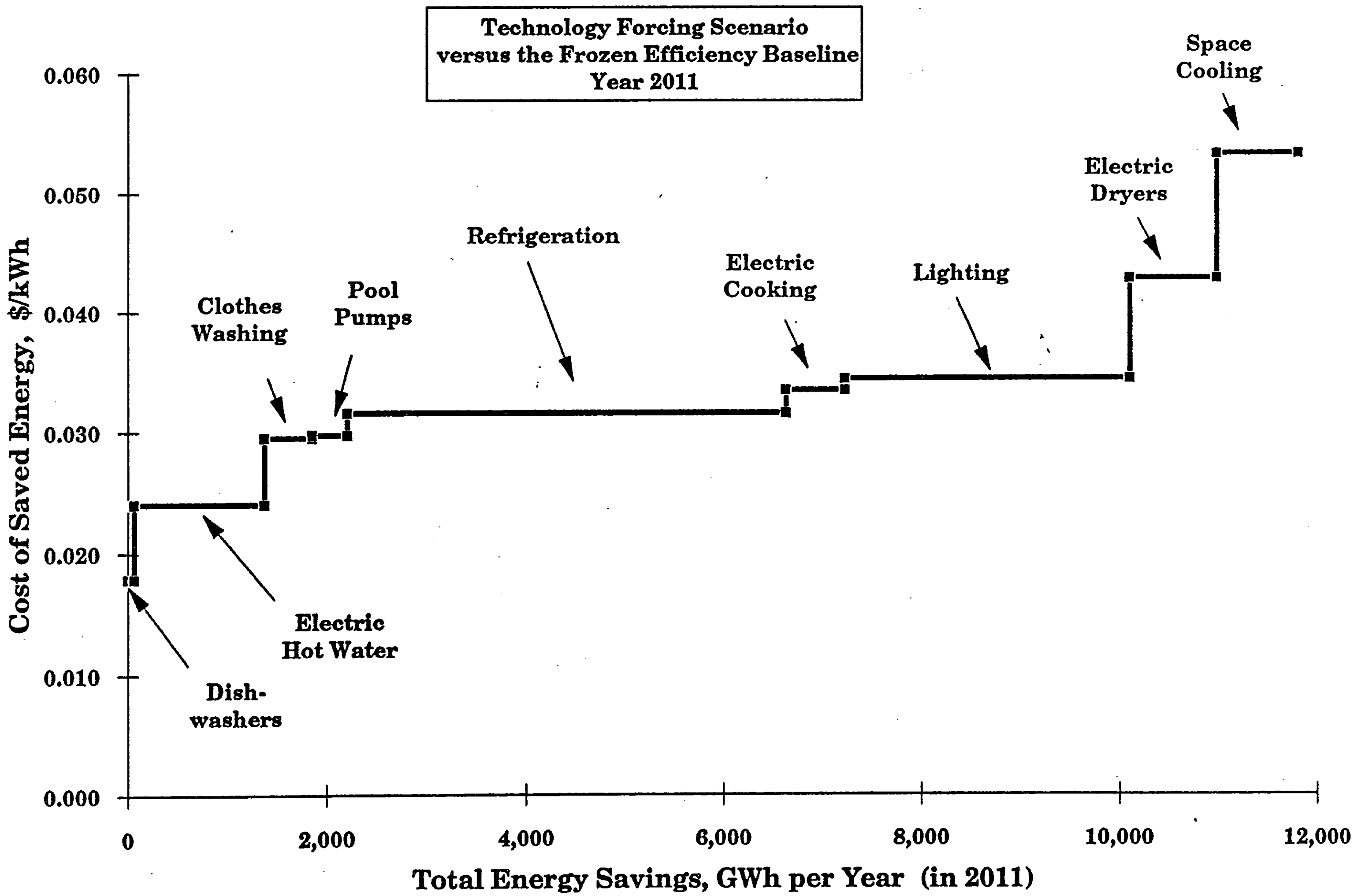

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Figure I-2
Residential Electricity Savings for the Utility Incentives Scenario
Year 2011

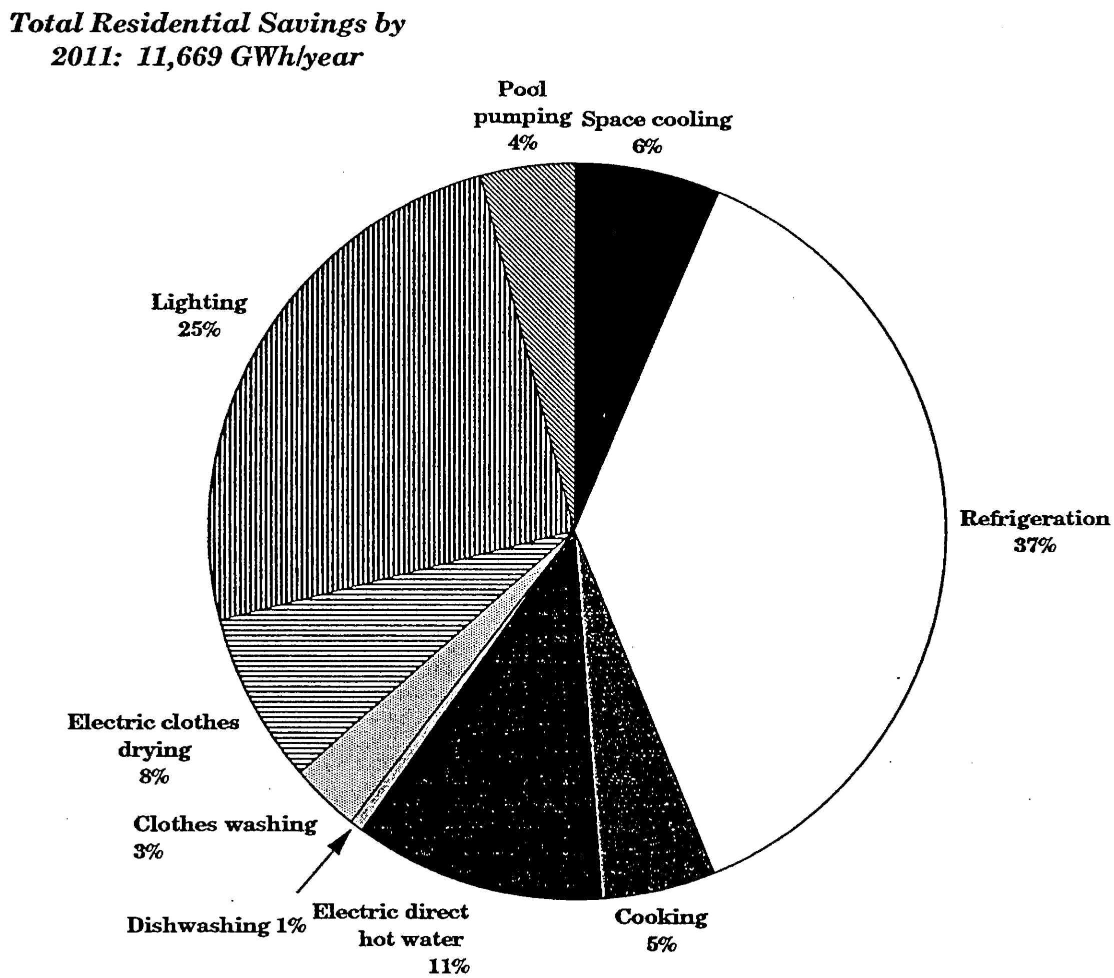

Figure I-3
Commercial Electrical Energy DSM Supply Curve for the California /District Region

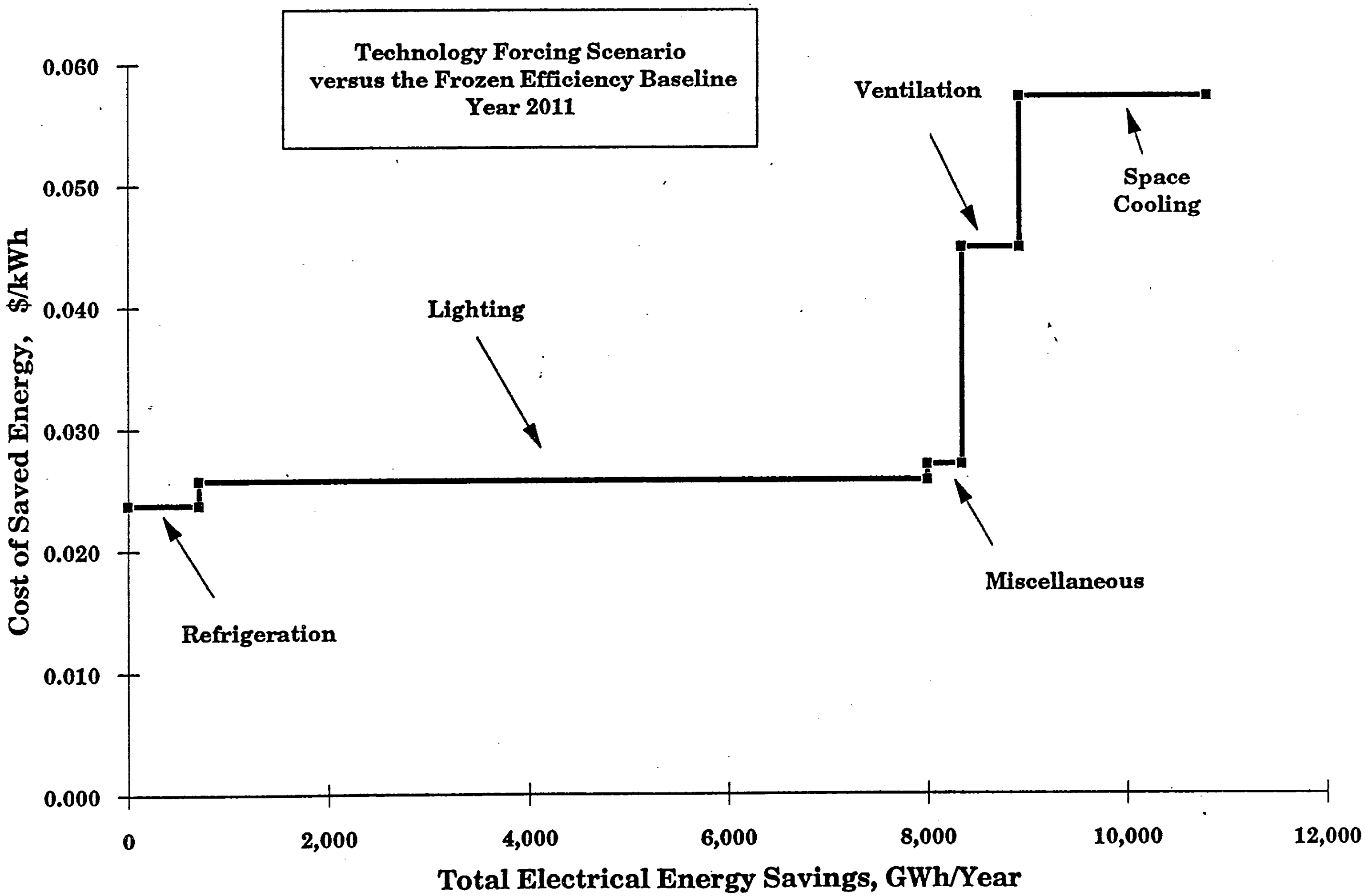

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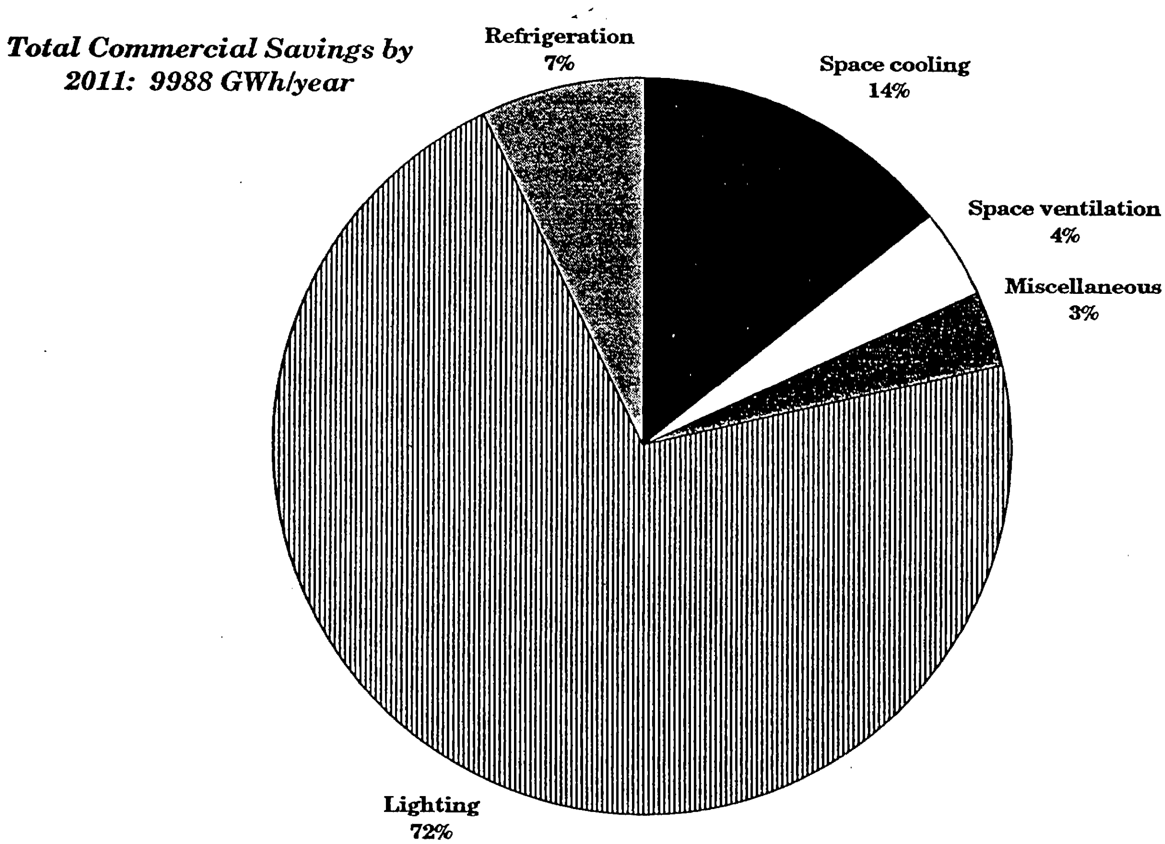
Figure I-4
Commercial Electricity Savings for the Utility Incentives Scenario
Year 2011



The industrial model used for the District did not analyze DSM savings for individual technologies. More importantly, the model did not analyze natural gas savings for core and noncore industrial customers. SCG currently does not offer DSM programs to its noncore industrial customers, and it is unlikely that SCG will offer DSM programs to noncore customers in the future. This is because the noncore market is highly competitive and essentially deregulated. In 1992, SCG's core customers used less than 9 percent of total industrial natural gas. Therefore, aggregating core and noncore customers in the model yields savings that are at least 10 times greater than what could be achieved for the core market through utility-sponsored DSM programs. For the industrial natural gas sector, the industrial model implicitly assumes that DSM incentives for noncore customers are provided by Federal, State, and local governments.

Under current regulatory requirements, SCG and the electric utilities are generally prohibited from promoting DSM measures with benefit/cost ratios less than one. This issue clearly makes the Technology Forcing scenario unrealistic in terms of current regulatory practice. In this regard, however, the issue of realism is less important than seeing what level of savings would be accomplished by increasing DSM expenditures beyond the standard economic threshold. Lowering benefit/cost thresholds is one way to ascertain the diminishing return to society from increaseing DSM investments. Chapter III provides detailed information on the DSM benefit/cost structure used in the modeling, and Chapter II provides information on the scenarios themselves. Using Frozen Efficiency as a baseline, total industrial natural gas savings for each scenario are 9.4 percent for Market Potential, 18.9 percent for Utility Incentives, and 21.7 percent for Technology Forcing. Total industrial electricity savings for each scenario are 7.7 percent for Market Potential, 16.1 percent for Utility Incentives, and 18.5 percent for Technology forcing.

D. SUMMARY OF VERMONT RESULTS

The Vermont analysis relied on the State's current version of its all-sectors energy model, ENERGY2020, to capture the effects of DSM program activities screened under the conditions specified for the two action scenarios, compared against the two baselines, Market Potential and Frozen Efficiency. For Vermont, the Market Potential baseline reflected current projections of demand for gas and electricity. It was essentially considered to be Vermont's BAU case. Incorporation of the second baseline, Frozen Efficiency, required modifying Vermont's model specifically for the project, reflecting the freezing of marginal, new device efficiencies at base year 1990 levels. Thus, the Frozen Efficiency case reflected no demand response to changing prices or other relevant market responses. Modifying ENERGY2020 to force this condition had the effect of bypassing the model's usual market responsiveness, considered by Vermont analysts to be the major strength of the model[1]. Using the model in this way may have caused some calibration problems which have not been thoroughly resolved. Thus, while the model was set up and run for both baselines, the Market Potential baseline probably represented the most robust results in terms of utilization of the economic tradeoff features of the Vermont

[1] A feature of the Vermont model is that some of the baseline conditions were integrated into the economic parameters of the model during running of the action cases; therefore, four action cases were run instead of the two required for the District region.

model. More detailed Vermont results, including the Frozen Efficiency baseline runs, are covered in Chapter VII.

The Vermont analysis centered on technologies identified in the residential sector. A limited review of technologies were also modeled for the commercial and industrial sectors. As a result of the resource-cost selection, however, no technologies were screened for the industrial sector, and the commercial sector only included the results of a handful of technologies, mainly electric air conditioning, lighting, and water heating. DSM technologies for natural gas were screened only for the residential sector.

Table I-5 shows the major results for Vermont's residential energy markets for the year 2010, compared against the Market Potential baseline. Overall, the results show a marked decline in the total demand for electricity and natural gas in the residential sector, with corresponding reductions in oxides of nitrogen (NO_x) and carbon dioxide (CO_2) emissions. As demonstrated in the table, residential electricity demand declined by approximately 7 percent by 2010 relative to the Market Potential baseline for the Utility Incentives case, wherein all technologies that passed the Total Resource Cost (TRC) test with a value of 1.0 or better were given DSM incentives.

Table I-5
Vermont Energy and Emissions Results
2010

	Market Potential Baseline (MP)	Utility Incentives	Percent Savings from MP	Technology Forcing	Savings from MP (%)
Residential Electricity Sales (GWh/year)	7,572	7,041	7.0	6,764	10.7
Residential Natural Gas Sales (MMtherms/year)	29.8	26.75	10.2	26.32	11.7
NO_x Emissions (tpy)	23.89	23.49	1.7	23.46	1.8
CO_2 Emissions (tpy)	8,344	8,158	2.2	8,147	2.4

Under the Technology Forcing scenario, in which all technologies with a TRC test of 0.7 or better were selected for incentives, residential electric energy demand declined 10.7 percent relative to the Market Potential base case. Sales of natural gas also showed a significant level of decline for 2010, with residential sales declining by almost 12 percent under that scenario. Natural gas, however, showed little difference between the Utility Incentives and the Technology Forcing scenarios. Under the Utility Incentives case, residential natural gas demand declined by 10 percent.

NO_x and CO_2 emissions also declined. On a *statewide* basis, NO_x declined by roughly 430 tons, or 1.8 percent, under the Technology Forcing case relative to the Market Potential base case. Under the same scenario, CO_2 reduction fell by 197 thousand tons

(2.3 percent) relative to the BAU base case, and fell by 184 thousand tons (2.2 percent) under the Utility Incentives scenario.

The differences in impacts between the Utility Incentives scenario and the Technology Forcing scenario in Vermont were not substantial, except in terms of electricity demand. A finer review of DSM potential in both the commercial and industrial sectors than that included in the Vermont analysis might yield substantially greater savings under both scenarios, however. Additionally, the Vermont analysis did not include retrofit opportunities in the scope of the screening and modeling. Including retrofit opportunities could substantially increase the cost-effective opportunities under both scenarios, especially over the shorter term (e.g., the year 2000 results).

CHAPTER II
POLICY OPTIONS AND TECHNOLOGIES INVESTIGATED

A. INTRODUCTION

This chapter provides a description of the energy efficiency policy scenarios developed for the project, as well as the regulatory policy environment in which their pollution prevention potential might be realized. As discussed in Chapter I, analysis centers on four scenarios: two baseline cases, which should bracket the expected BAU future, and two action cases that implement more aggressive policies to achieve greater efficiency and prevent further pollution. The Frozen Efficiency case reflects a situation in which demographics, stock turnover, and known (expected) changes in unit energy consumption patterns are the only controlling elements without new technologies beyond known standards changes. For the Market Potential case, in addition to these known trends, market penetration of new technologies without incentives is estimated. The two action options are Utility Incentives (with payments made by electric and/or gas utilities) and Technology Forcing. Options available to States and their subdivisions to implement the action scenarios are also discussed.

Two other possible scenarios were considered, but were not developed for the project. These were a stringent efficiency standards case and a "no-holds-barred" technical potential case. The first was rejected because it was assumed that most of the politically viable energy efficiency standards potential has been incorporated into existing Federal legislation, such as the regulations of National Appliance Energy Conservation Act of 1987 (NAECA), augmented by the current State codes, so that the baseline cases effectively subsume and bracket the "standards" case. The maximum technical potential scenario was rejected because it would ignore technology or DSM measure cost/benefit, and would therefore essentially be a measure of the model's efficient technology coverage (the extent of its energy reduction supply curves) -- a possible desirable model assessment activity but not a scenario representing a reasonable 20-year future.

B. SCENARIO DEFINITIONS

The baseline scenarios (Frozen Efficiency and Market Potential) are predicated on a current set of energy and load forecasts for the utilities in the geographic areas analyzed. For the District analysis, these include the existing DSM programs of SCE, LADWP, BGP, SCG, and California building code and appliance efficiency provisions. The Frozen Efficiency case essentially needs no discount rates or TRC tests, since no new technologies other than that representing the first "step" on the energy conservation supply curve, or the unit of energy consumption (UEC), is applicable. For treatment of the societal costs and benefits of DSM programs in the Market Potential case, a 10 percent real discount rate was assumed. This rate, while higher than the rate used by most utility DSM submissions, nevertheless appeared to most of the project participants to represent the "actual" discount rate that has been applied to DSM activity.

The Utility Incentives scenario presumes a 100 percent buydown of the incremental cost for all cost-effective technologies and measures, with a 2 percent real discount rate assumed for calculating the present value of delayed benefits or costs. The criteria for including a measure is that the cost of saved energy must be less than the utility's avoided cost, including environmental externalities. The measure's cost is the actual difference in price between the efficient measure and the "base" standard measure, as found in the market today.

The Technology Forcing scenario would use available regulatory and economic levers, including air quality regulations, building codes, zoning and siting regulations, and "golden carrots" (new technology incentive programs) to foster commercialization and high market penetration of improved technologies beyond the earlier cases. In this scenario, commonly used measures of benefit, such as TRC and cost of saved energy (CSE) of emerging technologies (such as solar domestic hot water heaters and advanced refrigerators) are calculated from projected costs of mature technologies. A 2 percent real societal discount rate is also used in this scenario.

C. DISCOUNT RATES

Discount rates are an important consideration in scenario specification. They are used to calculate the CSE and TRC test. While in most cases the real discount rate was used, both nominal and real (inflation-adjusted) discount rates were developed so that a present value could be calculated for any time-series forecast of cost streams, given either in nominal or real terms. Rates for participants, utilities, and "society" were differentiated and used separately, as discussed below. A more complete discussion is provided in Appendix A.

1. Participants

Energy conservation consumers, including DSM program participants, have traditionally been skeptical about energy efficiency claims and have required high payback rates (short intervals for cost recovery) to invest in energy-saving devices or programs. The 10 percent to 35 percent range of participant's (real) discount rates adopted in this study is low by standards of the research literature, in which implicit consumer discount rates of over 100 percent are often found for energy conservation investments. However, the market penetration methods used for each of the two regions included other algorithmic structures which only peripherally utilized this rate. For instance, the District model did not use the participant's rate; instead, a collection of market feasibility/applicability factors and a payback/acceptance equation was used for market penetration.

2. *Utilities*

The appropriate discount rate for utilities is the risk-adjusted cost of capital for their investments. On the one hand, DSM investments could be considered somewhat more risky than traditional supply-side investments, since the field is less mature and evaluation methods are not well proven. On the other hand, the increments of DSM capacity are small, so there is much less risk of major losses than with traditional solutions. These factors were considered to balance one another. For all three scenarios, a 6 percent real discount rate was assumed for utilities where model calculations required them. This rate was close to published rates used for utility DSM submissions (e.g., an 11.11 percent nominal rate was used by SCE in its 1992 DSM analysis).

3. *Society*

The societal discount rates used for the action scenarios were much lower than the market rates of the utility or DSM program participant. They reflect the long-term interests of society, including interest in internalizing costs that are not now captured and assigned to the energy conversion industry. A variety of values have been used in similar analyses. The project participants tended to agree that societal discount rates used for the project scenarios should be within the 2 percent to 4.6 percent (real discount -- that is, in addition to inflation) range of a comprehensive 1982 study of societal discount rates (Lind et al., 1982). In agreement with an initial guideline for the study, which was to investigate the effects of low discount rates on DSM measure conservation, a societal real discount rate of 2 percent is assumed for the Incentives and Technology Forcing scenarios. This rate is somewhat lower than the 3 percent rate that apparently has been commonly used for California policy studies. For the Market Potential scenario, however, a 10 percent real discount rate was used, reflecting an assessment of the actual societal weighting which has affected DSM measure programs and participation, especially prior to the heightened activity which began in 1990 with the California Collaborative Agreement and similar policies in other areas of the country (notably New England, New York, and Wisconsin) and the resulting interest in expanding DSM programs.

D. DETAILS OF THE SCENARIOS

As stated earlier, this study examined four scenarios: two baseline scenarios, which essentially bracket the expected future, given continuation of present utility and construction practices in the two case study regions, and two different action routes, which are directed toward greater energy efficiency and less pollution. Each scenario is defined by the following characteristics:

- The policy environment *definition*, that is, the regulatory strategies utilized to achieve pollution prevention goals in the given scenario. For example, the Incentives scenario operates both by giving energy utilities incentives for saving energy and avoiding pollution, and by giving utility customers financial incentives for choosing more efficient approaches.

- A *list of policies* that are required to implement the strategy, which include a detailed set of requirements that programs must adhere to within the scenario.

For example, the Incentives scenario requires the utility to "buy down" the full incremental cost of cost-effective efficiency upgrades.

- A *list of technologies* that represent the most promising technologies applicable to the highest-use energy service classes and how they would change based on the policies included in each scenario. (This, of course, is highly region-specific due to climatological effects on energy intensity.)

Details of the scenarios, outlined in terms of each of these qualitative aspects, are given below.

1. *The Frozen Efficiency Baseline*

a. *Definition*

The Frozen Efficiency baseline gives the expected upper limit of energy demand growth and is essentially an element of model calibration and documentation. It makes the following assumptions for the 1992 through 2011 forecast horizon:

- Most recently adopted public utility commission and/or energy commission growth projections; and

- Incorporation of Federal and State energy standards already in place. These standards apply to appliances, lighting, equipment, and building shell measures. Such standards affect the expected unit energy consumption (UEC) and energy use intensity (EUI), which are average end-use class usage levels of the affected energy sectors. New standards for additional product classes which were required by the Energy Policy Act of 1992 were not included, as these were not in place in time to be assessed for the project.

- The scenarios for industrial sector natural gas include both core and noncore customers. SCG currently does not offer DSM programs to its noncore industrial customers, and it is unlikely that SCG will offer DSM programs to noncore customers in the future. This is because the noncore market is highly competitive and essentially deregulated. In 1992, SCG's core customers used less than 9 percent of total industrial natural gas. Therefore, aggregating core and noncore customers in the model yields savings that are at least 10 times greater than what could be achieved for the core market through utility-sponsored DSM programs. For the industrial natural gas sector, the model implicitly assumes that DSM incentives for noncore customers are provided by Federal, State, and local governments.

The Frozen Efficiency scenario utilizes current utility forecasts for energy growth; savings from DSM programs are only those which are expected from normal stock changeover upon burnout or demolition. No discount rate is needed for this scenario, since no "choice" is being made and no utility DSM programs are applicable.

b. Policies

The Frozen Efficiency baseline scenario assumes no change in the present policies by government or utilities.

c. Technologies

This scenario freezes technologies at the *first* increment of the conservation supply curve for new building/end uses. In general, the average UECs for new end uses are lower than those of existing stock; however, this is not always the case. The UECs of new single-family residential space cooling in California were found to be *higher* than the existing UECs, for instance. This aberration was caused by a forecast with increased air conditioning use per dwelling, as well as increased square footage per household. The new-stock UECs reflect new Federal and State regulations; in particular, California's Title 24 building standards, among the stronger codified State efficiency provisions, are considered for all of the District results.

2. The Market Potential Baseline

a. Definition

The Market Potential baseline scenario allows full market penetration of new technologies without any government and/or utility action other than market forces. The following constant assumptions were made for the forecast horizon:

- Continuation of California and Vermont energy codes in place as of January 1993 for buildings and appliances before the year 2010.

- Continuation of current air quality regulations for the District.

- Continuation of planned Federal appliance and lighting standards in NAECA. New standards for additional product classes which were required by the Energy Policy Act of 1992 were not included, as these were not in place in time to be assessed for the project.

- Current utility forecasts for energy growth and savings from pre-1990 DSM programs.

- A 10 percent real discount rate for any economic calculations which might be required by the model(s).

Implementing DSM in the District region involved six utilities, and special assumptions needed to be made about these utilities. As government-owned utilities, LADWP and the three smaller municipals do not have the same financial incentives as do SCE and SCG, but it is assumed here that programs congruent to those of SCE are implemented for two reasons. First, common sense: Given a single marketing area, equivalent programs available in all parts of the media market reduce customer confusion. Second, least-cost planning: In reality, LADWP and SCE differ in their reserve margins and in the higher cost of capital and higher estimates of avoided cost for SCE. For the purposes of this study, however, it is assumed that the utilities find the same programs to be justified, that both utilities have joined the one existing golden carrot program, and that they have announced jointly the same CO_2 reduction targets suggests this assumption may be close enough.

b. Policies

The Market Potential scenario requires no change in the present policy environment for investor-owned electric utilities. It is assumed that they execute core programs (low-cost housing, education, etc., on a cost-recovery plus handling fee basis) and other programs with the incentive of a share of the saved energy, plus cost recovery. In this scenario, it was assumed that voluntary decisions or State-imposed requirements of municipal utilities match the DSM programs of the investor-owned utilities.

c. Technologies

The Market Potential baseline allows the free range of technologies to compete freely in the marketplace. New technologies that are implied by current standards will be applied by stock attrition. In addition, existing stock replaced prior to burnout or building thermal integrity measures retrofitted prior to demolition are available at incremental cost.

3. The Utility Incentives Scenario

a. Definition

The Utility Incentives scenario estimates the effects of a societal decision to utilize energy utilities as the agents of efficiency improvement. Compared to the Market Potential case, improvements in the Incentives scenario are driven by expanded utility rebates or other buydowns to the full incremental cost of new technologies. It is assumed here that each year the utilities will offer 100 percent of the incremental cost for all improvements that meet the TRC test using the societal cost of capital (2 percent real discount) and an estimate of avoided societal cost (damage) of emissions (limited to CO_2 and NO_x damage) at generating stations for electricity and at customer sites for natural gas. In contrast with the next scenario, the Incentives scenario does not remove the most inefficient legal and code-compliant measures from the marketplace. In this scenario, there is continuing improvement in average efficiency, insofar as incentives may be expected to lead manufacturers to offer more efficient units, and as construction practices gradually improve in response to utility incentives.

The penetration rates for each technology and measure are estimated by the models using their respective algorithms for measuring cost/benefit and participant market response. Within the Incentives scenario, penetration rates are affected by two major factors: increasing levels of market penetration of technologies for which incentives are provided, and increased efficiency of technologies that receive incentives. For competitive reasons, this strategy is designed to lead both to improvements in energy efficiency and to reductions in costs, because the utility incentives should increase competition in the energy service class, with resulting economies of scale. The Incentives scenario does not remove the least efficient units from the market, however; it therefore has lower penetration rates for installed units and measures than the Technology Forcing scenario.

b. *Policies*

The Incentives scenario allows electric utilities to recover DSM costs and receive a financial incentive as a share of the value of saved energy. As applied to California, this scenario treatment is extended to gas utilities, allowing them to bring solar hot water heaters to market there. In treating solar heaters as gas DSM measures, the gas utility is assumed to be allowed to capitalize these appliances as though they were like the gas distribution system (pipes, valves, storage tanks, etc.). Because the value of avoided gas space heating is less than the value of avoided air conditioning[2], building shell measures in areas like the District with balanced heating and cooling UECs are therefore considered to remain mainly under the auspices of electric utility DSM programs.

c. *Technologies*

The relatively low 2 percent discount rate for calculating the net present value of avoided emissions benefits results in a high number of technologies being "bought down" under the Utility Incentives scenario. For the California model, which explicitly delineated individual technologies, about 40 percent of the technologies were thus targeted for DSM incentives. These included the following:

Building Shell and Space Conditioning --

- Higher performance fenestration, including double-pane and low emissivity windows;
- Improved wall and ceiling insulation for both residential and non-residential buildings;
- Residential infiltration and duct leakage testing and controls;
- Improved residential central air conditioners and heat pumps;
- Light-colored roofs; and
- High-efficiency commercial central chillers and direct expansion AC (to EER=11).

Lighting --

- Compact fluorescents and halogen PAR floods; and
- Occupancy sensors, electronic ballasts, and improved reflectors for commercial fluorescents.

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[2]For instance, avoided natural gas in Southern California is valued at about 23 cents per therm, and avoided electricity costs at about 3.5 cents per kWh. An air conditioner with a 10 SEER produces 10,000 Btu of cooling load per kWh at the meter, or 0.1 therms. So the energy usage rate would be 10 kWh per therm of cooling load. If the utility had transmission and distribution losses of 7 percent, the avoided electricity cost, not including avoided power (load) cost, would thus be 3.5*10/.93 = 37.6 cents per therm of cooling load -- substantially more than the 23 cents of avoided gas. This effect is generally found in all areas of the Unites States.

Appliances and Water Heating –

- High-efficiency residential and commercial refrigerators and freezers;
- Heat pump water heaters and low-flow devices;
- Bi-radiant and convection ovens; and
- High-efficiency residential clothes washers, dishwashers, and clothes dryers.

4. The Technology Forcing Scenario

a. Definition

Many "super-efficient" technologies and building methods have been demonstrated in the laboratory or in small quantities in the field, but are not cost-effective with their present production volumes and marketing costs. Examples of such measures include air conditioning, efficient window construction (fenestration measures), and solar hot water heating. The Technology Forcing scenario attempts to measure the benefits, including pollution prevention effects, of producing these technologies in large enough volumes that they become cost-effective in a societal sense, and then, after an appropriate delay, become a robust market-driven participant in their respective energy service classes.

The screening mechanism employed for inclusion of the technologies in the class to be "forced" was the determination whether the measure's TRC/societal benefit would fall between 70 percent and 100 percent of its net cost or, equivalently, whether the measure's TRC benefit/cost ratio would be at least 0.7, but would not exceed 1.0. (Those technologies with TRC greater than 1.0 would pass and be given utility DSM incentives without special dispensation.) This procedure involved two cost-reduction actions: (1) as in the Utility Incentives scenario, all technologies exceeding TRC ratios of 0.7 were given a 100 percent utility buydown of their incremental cost; and (2) those measures with TRC falling between 0.7 and 1.0 which would not have "passed" TRC under current cost/market conditions were assumed to be subject to special targeted societal efforts to lower their costs and thereby increase the future market penetration of the technology.

Technology Forcing evaluates the potential of efficiency levels that are not currently cost-competitive in the market, either from a societal or participant's perspective. The process involves several steps to identify costs, the product's technical status, and market characteristics for the candidate technologies. The next step in the process evaluates how much cost reduction and production increase is required before these technologies would pass a "societal" measure of merit, such as the TRC test. The goal is to show the air quality and energy impacts that would result if the cost reductions and resulting high market penetrations occurred.

The penetration rates for each technology and measure are estimated by the models using their respective algorithms for measuring cost/benefit and participant market response. In this respect, the market penetration methodology is identical to that used in the Utility Incentives Scenario.

b. Policies

Three Technology Forcing policy mechanisms have been applied to energy conservation, and thus may be considered to be tested and viable policy options. These three policy alternatives are discussed in this section.

The first uses utility-sponsored *golden carrot* competitive programs to pull technologies into the market and drive their costs down; it also uses government standards to raise the market to the new technology level. In this program, utilities in collaboration with manufacturers that receive regulatory permission guarantee a reasonably large market for new or improved technologies if they are brought to market at cost-effective prices. For example, at the end of 1992, the Super-Efficient Refrigerator Program, a collaboration of about 20 utilities, issued a Request for Proposals for refrigerators that will work at least 25 percent better than the 1993 NAECA standard. If these come to market as expected, they will demonstrate the viability of the golden carrot approach and the cost-effectiveness of advanced refrigerators. In turn, they may lead to larger utility programs or 1998 NAECA regulations that will make such refrigerators the expected norm in the marketplace. One noteworthy aspect of the golden carrot programs is the minimal risk to utilities and their ratepayers; little money is lost if the anticipated number of units are not produced, since the incentives are based on units *delivered* to the market.

The second option is to drive promising technologies through *regulatory mandates* (e.g., air quality regulations) to send a signal that there is a large, regulation-driven market for advanced technologies. This is the strategy that led to computer-controlled automobile engines that optimize performance and mileage while decreasing emissions. With sufficient advance notice, authorities can target certain advanced technologies, such as the zero emission vehicle regulations of the California Air Resources Board and the alternate fuel requirements and incentives in the 1990 amendments to the Federal Clean Air Act (CAA). Such regulations, by guaranteeing a minimum market size, have the potential for directing investment, leading to less expensive technical solutions than originally forecast.

The third approach, *substitution*, would use either utility incentives or regulation to guarantee a place in the market for customer-side fuel substitutions that reduce pollution. An example of this policy is the natural gas-assisted solar domestic hot water program that is being considered as a mandated replacement system for certain commercial buildings in Southern California.

These options -- golden carrots, mandatory regulations, and substitution -- are not differentiated in terms of specific scenario cost elements, but for the purposes of the project were considered equivalent vehicles for driving technology forcing.

c. Technologies

The Technology Forcing scenario extended the technologies of the Utility Incentives scenario by adding those with TRC tests that fell between 0.7 and 1.0. Since the TRC calculation is made for each specific building type and end-use sector, the measures to which policies such as golden carrots would be applied were specific to the building type (residences, offices, food stores, schools, apartments, etc.) and method of introduction (i.e., whether for retrofit or new construction). While a complete list of measure/building-type/sector combinations would be too large to practicably enumerate here, a sample run of the California model resulted in the following measures being added to those in the Utility Incentives scenario by lowering the TRC threshold to 0.7 from 1.0 for residential and large office applications.

Residential Measures Added --

- Double-pane and low emissivity windows (for multi-family only);
- Multi-family infiltration and duct leakage testing and controls;
- Refrigerator maintenance package;
- Hot water savers;
- High-efficiency direct hot water heater-to-energy factor = 0.61; and
- High-efficiency vertical axis clothes washers.

Commercial Large Office Measures Added --

- High-efficiency boilers (E.F. = 0.82);
- Variable speed drive (VSD) motors for chilling, ventilation, and display cases;
- Water-cooled direct expansion chillers;
- Window film;
- Stepped dimming light fixtures; and
- High-efficiency water heaters.

E. SUMMARY/CAVEATS

The Frozen Efficiency baseline scenario is a straightforward compilation of the expected energy use in the absence of utility DSM programs or new technology market penetration. The only way energy use will change in this scenario is through demographic change, building stock intensity change, and stock changeover through demolition and replacement to the least efficient new technology in compliance with State and local regulations.

The Market Potential scenario is comparable to the projections of the National Energy Strategy or the baselines in other studies, insofar as some of the energy conservation trends, resulting in lower UECs, have been catalyzed to some extent by utility DSM efforts. Its major value is to acknowledge that forecasts now include significant energy efficiency targets destined to be achieved through current utility DSM programs, and that these efforts will eventually measurably dilute the potential benefit of new energy conservation technologies.

The Technology Forcing scenario is comparable to some published "technical potential" studies, except for the willingness to forecast a policy-induced lowering of market prices for advanced technologies that are expected to have significant potential for reduced total costs in much larger markets (e.g., gas-assisted solar domestic hot water heaters).

The Incentives scenario represents an intermediate point between the two baseline scenarios and Technology Forcing. It works to improve average efficiency by giving manufacturers reasons to make and promote better products. It does not remove the most inefficient units from the market. In contrast to a "standards" approach which, as discussed earlier, was considered for the project but later rejected (mainly since the baseline scenarios carried forward all known changes in current energy standards), the Incentives scenario would remove the least efficient products more rapidly than the Technology Forcing scenario (as interpreted here), but would tend not to encourage the introduction of more efficient technologies.

Both of the action scenarios assume a 100 percent buydown, implemented by utility DSM programs, of the incremental costs of efficient measures passing TRC. This action adds to the total societal cost of the measures an amount equal to the program administrative costs (excluding actual incentives) incurred by the utilities. To address this issue, a 20 percent overhead/administrative fee was added to the cost of all measures as an integral part of the TRC/societal calculation.

The measures to be given further socially driven market impetus in the Technology Forcing scenario were selected on the basis of a simple one-dimensional selection criteria (the TRC ratio), which only measures per-unit costs and per-unit savings, without regard to total potential measure impact in the study region. Any special study focusing on such technology-screening issues needs (at a minimum) to extend the screening methodology to a two-dimensional level to not only provide the *unit* benefit/cost, but to also address the relative *total* benefit of the measure, assuming expected market penetration given the new policy. More extensive research would integrate both supply- and demand-side possibilities for policy-driven cost reduction of emerging technologies such as solar collectors.

CHAPTER III
ANALYTIC ISSUES IN DSM ANALYSIS

A. OVERVIEW

During the preliminary analysis and research of the modeling methodologies and data bases available for forecasting energy conservation potential, it became apparent that the state of the art in DSM/conservation forecasting is not well developed. Even within utilities and consulting firms considered to be leaders in the field, the DSM-oriented data development and model calibration activities are far from complete. Probably the main reason is that the field involves interplay of a daunting array of specialties: technologies, political entities, fuels, weather effects, architectural and engineering knowledge, and behavioral factors. This section outlines some of the key issues and analytic concepts required for energy conservation analysis. The issues fall into several major categories:

- Demographic and macroeconomic issues;
- Climate;
- Trends in energy standards;
- Technology screening (and related issues of avoided cost, emissions damage, and discount rates); and
- Estimating measure market penetration.

These issues are discussed below as they apply to the analysis of conservation impacts on energy consumption and emissions.

B. DEMOGRAPHIC AND MACROECONOMIC ISSUES

Despite major legislation and policy initiatives to encourage energy conservation since the first oil crisis of 1973, energy use in buildings in the United States increased from 22 quadrillion Btu (quads) to about 30 quads in 1989. Three major factors influenced this increase: (1) an increase in population, by about 45 million from 1970 to 1990, (2) a major, unexpected decline in average household size, from 3.24 people per household in 1970 to 2.68 in 1990, and (3) a general increase in demand for energy-intensive services like residential air conditioning. The population and household size trends have alone accounted for a 50 percent increase in the number of households in just 20 years.

From the standpoint of the DSM/conservation analysis, these facts must be addressed in estimating trends in stock of energy-using building space and equipment. The California DSM model used utility forecasts of growth in each utility's service area in terms of households and commercial/industrial square footage, presumed to include estimates of average household size, together with trends in the UECs of end-use competitive classes attributable to current and projected Federal and California Title 24 energy use regulations and standards for new building shells, lighting, motors, and appliances. For Vermont, the population, income, and other demographics affecting growth were imbedded in the macroeconomic forecast of the Regional Economics Model, Inc. (REMI) model.

C. CLIMATE

Weather (temperature, humidity, precipitation, and wind speed) is the principal determinant of building energy use; it therefore offers another dimension to technology selection analysis. As is clear from the study results, the low UECs for the District's weather-sensitive end-use classes, due to Southern California's comparatively mild climate, act to lower the value of efficient heating, ventilation, and air conditioning (HVAC) systems, insulation, and air infiltration measures. As Table III-1 illustrates, these weather patterns vary widely across the United States. The table shows mean heating and cooling degree-days (from a base of 65°F) for Federal regions using a representative city to represent the mean, and average heating and cooling loads, or required energy, for new prototypical residential buildings that were developed by Lawrence Berkeley Laboratories (LBL) in a recent study (1991). Mean heating degree-days by Federal regions vary from a low 2,107 with a centroid represented by Los Angeles, to a high in Detroit/Ann Arbor of 6,387 – a three-to-one ratio. Cooling degree-days vary even more: from 212 in Seattle to 2,600 in Shreveport, Louisiana.

Table III-1
New Residential Heating and Cooling Loads by Federal Region

Federal Region	Closest City to Mean	Mean Heating Degree-days (HDDs)	Mean Cooling Degree-days (CDDs)	Heating Load (MMBtu/year)	Cooling Load (MMBtu/year)
1	Boston, MA	5,732	675	192.0	17.9
2	New York, NY	5,414	913	150.3	27.5
3	Philadelphia, PA	5,024	1,000	168.6	33.2
4	Jackson, MS	2,349	2,330	69.7	62.4
5	Detroit/Ann Arbor, MI	6,387	757	196.9	22.4
6	Shreveport, LA	2,138	2,600	60.4	74.0
7	Kansas City, MO	5,328	1,311	162.6	50.6
8	Denver/Boulder, CO	6,044	703	173.8	20.0
9	Los Angeles, CA	2,107	934	36.5	6.0
10	Seattle, WA	5,183	212	194.7	7.0
US Average	Baltimore, MD*	4,392	1,194	131.7	47.3

NOTES: Baltimore was considered to represent the national average for HDDs and CDDs.

Given the wide variation in energy use (and therefore energy conservation potential) across climate zones, a major analytic decision point in any DSM/conservation impact analysis will be to decide the degree of aggregation into separate climate zones that the underlying data can support. California has 16 such zones, for instance, as shown in Figure III-1, and the District region contains 7 of them. To account for these wide differences in baseline energy use, the DSM analysis data used by SCE in its COMPASS model is divided into the (California) weather zones covering their service area. The modeling for this study, however, used aggregated UECs and stocks for the entire District.

D. ENERGY STANDARDS

Since 1975, Congress has produced five major energy conservation-oriented bills, plus an array of modifications and regulations to existing law. The major Federal legislation is described in Table III-2. The major content of these bills focused on low-income energy assistance, voluntary building and efficiency targets, appliance labeling, and Federal building codes. The NAECA was the major milestone in appliance standards, and was the basis for much of the efficiency trends in the BAU scenarios of this study. Table III-3 contains a list of the major Federal appliance standards that are either currently in place or scheduled for activation by 1995. The latest Federal legislation, the Energy Policy Act of 1992, established mandatory building efficiency standards and a voluntary efficiency rating system for all new residential buildings.

E. TECHNOLOGY SCREENING

One of the first steps in developing a DSM analysis is to decide on a procedure for ranking candidate technologies within a particular market segment by some measure of benefit and cost. The benefits of energy conservation are highly variable, however, and are not always apparent. In addition, the same technology's relative merit may change considerably between markets, as UECs or load impacts, and resulting savings may change. Within the same market segment, four distinct benefits for each technology/measure were incorporated into the analysis. These were as follows:

- avoided energy, in kWh of electricity or therms of oil or gas;
- avoided or delayed electric utility plant capacity, or load;
- avoided electric utility generating station emissions; and
- avoided natural gas emissions at the burn site.

The avoided electric and gas energy costs, representing mainly fuel and variable costs of supplying incremental energy, were available from published utility documents, and are generally straightforward in terms of understanding and ease of computation. For electricity, assumed transportation and distribution resistance losses are added to energy savings before the total avoided energy benefits are calculated.

Figure III-1 California Climate Zones

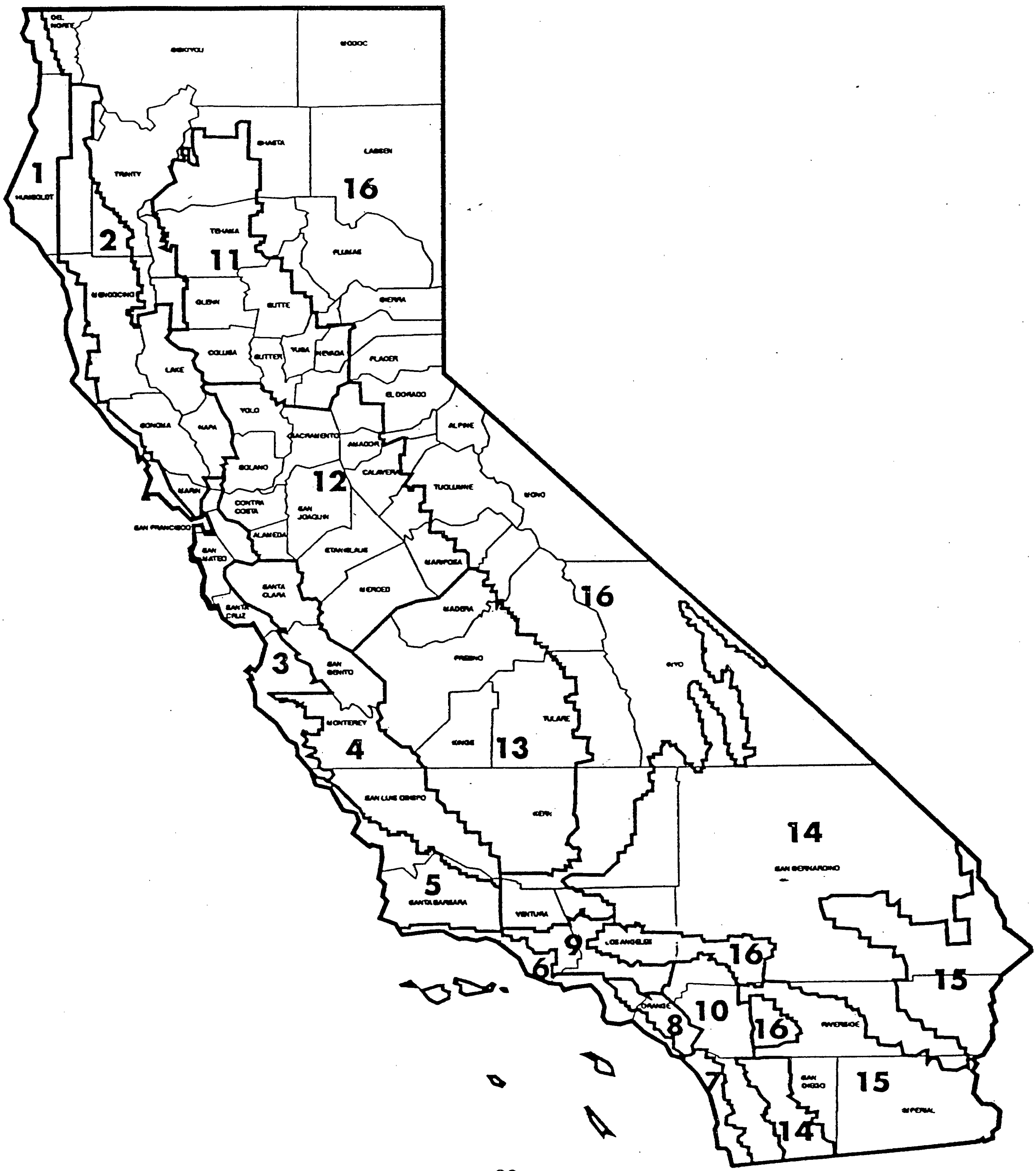


Table III-2
U.S. Energy Conservation Legislation

EPCA	Energy Policy and Conservation Act (Public Law 94-163; December 22, 1975). Directed FTC to develop labels for energy use in new appliances; directed FEA (later DOE) to develop voluntary appliance efficiency standards. Established State Energy Conservation Program to provide technical assistance to States on energy conservation.
ECPA	Energy Conservation and Production Act (Public Law 94-385; August 14, 1976). Required the development of national mandatory Building Energy Performance Standards (BEPS) for all new U.S. buildings; later made voluntary for non-Federal buildings by (Public Law 97-35). Created weather assistance program for low-income households.
NECPA	National Energy Conservation Policy Act (Public Law 95-619; November 9, 1978). Established the Residential Conservation Service, requiring large electric and natural gas utilities to provide energy audits to their customers; required the voluntary appliance efficiency targets being developed under the Energy Policy and Conservation Act to become mandatory standards; required the national mortgage associations to encourage lending institutions to offer extended mortgage credit for the purchase of energy-efficient homes.
NAECA	National Appliance Energy Conservation Act (Public Law 100-12; March 17, 1987, as amended in Public Law 100-357). Established energy standards for 13 categories of new appliances covered under EPCA, as amended. Requires DOE to review and update these standards to keep pace with technological improvements.
EPA92	The Energy Policy Act (Public Law 102-486, October 1992). Previously House Bill 776, EPA92. EPA92 establishes a Director of Climate Protection in DOE, requires DOE to provide a least-cost energy strategy to stabilize and reduce greenhouse emissions, and directs DOE/EIA to establish a national inventory of greenhouse gas emissions. Establishes mandatory Federal building energy-efficiency codes and voluntary efficiency ratings for new residential buildings. Efficiency standards are explicitly specified for showerheads, motors, and lighting/lamps.

Table III-3
Representative Federal Appliance Standards as of January 1993

Appliance	Product description	Effective date	Standard	Notes
Refrigerator-freezers	Automatic defrost, top-mounted freezer, without through-door ice service.			
		1/1/90	23.5*AV+471 maximum kWh/year	AV = adjusted volume = 1.63 * freezer volume + refrig vol., in cubic feet (ft^3)
		1/1/93	16.0*AV+355 maximum kWh/year	For example, if cross-top freezer holds 5 cubic feet, and refrigerated space is 15 ft^3, then AV = 1.63*5+15, or 23.2 ft^3, and the maximum allowable UEC would be 726 kWh/year in 1993.
Room Air Conditioners	Without reverse cycle, >= 20,000 Btu/hour	1/1/90	8.2 Energy Efficiency Ratio (EER)	
Central Air Conditioners and Central Air Conditioning Heat Pumps	Less than 65,000 Btu/hour, air source, single package systems	1/1/93	9.7 SEER (cooling mode), 6.6 HSPF (heat pumps only)	SEER = Seasonal energy efficiency ratio HSPF = Heating season performance factor
	Less than 65,000 Btu/hour, air source, split systems	1/1/92	10 SEER (cooling mode), 6.8 HSPF (heat pumps only)	
Water Heaters, Electric	Storage type, <= 120 gallons capacity, <= 12 kW input rating	4/15/91	EF >= .93-.00132*V	EF = energy factor V = storage volume in gallons
Water Heaters, Gas	Storage type, <= 100 gal. cap., <= 75,000 Btu/h	4/15/91	EF >= .62-.0019*V	
Showerheads	Measured at a flowing water pressure of 80 pounds per square inch.	7/1/92	2.5 gpm	(or the ANSI published standard, whichever is less)
Lavatory and sink faucets			2.2 gpm	

Table III-3 (continued)

Appliance	Product description	Effective date	Standard	Notes
Gas furnaces		1992	78.0% AFUE	
Dishwashers	Standard dishwasher, equal to or greater than 22 inches in width	1994	0.46 EF, plus must have an option to dry without heat	EF = energy factor in wash cycles per kWh
Clothes Washers	Top loading standard, 1.6 ft^3 or greater capacity	5/14/94	1.18 EF	EF = energy factor in ft^3 * (cycles per kWh)
Clothes Dryers, Electric	Standard 4.4 ft^3 or greater	5/14/94	3.01 EF	EF = energy factor in lbs per kWh
Clothes Dryers, Gas	Standard 4.4 ft^3 or greater	5/14/94	2.67 EF, no constant pilots allowed (since 1988).	
Ranges and ovens, Gas	All	1990	No constant pilots allowed.	
Pool heaters	All	1990	Thermal efficiency of at least 78%.	
Fluorescent lamps	4 foot, >35 nominal watts	1996	minimum CRI = 69, minimum average lamp efficacy = 75.0 LPW.	CRI = "color rendering index," a measure of color shift of illuminated objects. LPW: lumens per watt.
Fluorescent lamp ballasts	Standard fixture, input voltage 120 nominal, at 60 hertz, with two F40T12 lamps	4/1/91	Ballast efficacy factor >= 1.060	Equivalent standards apply also to F96T12 and F96T12HO lamps, at 120 or 277 volts.

SOURCE: 1. 10 *Code of Federal Regulations* 430.32.
2. H.R. 776, draft, July 30, 1992 (precursor to the Energy Policy Act of 1992).
3. ASHRAE, 1989.

Load impacts are sometimes extremely important in assessing the relative value of technologies within a market. Measures that are likely to operate coincident with the system's peak-load season -- like efficient air conditioners in the South or electric heat pumps (replacing resistance heaters) in the North -- show higher avoided cost values than measures which operate most of the year, when the value is calculated on a per-kilowatt-hour-saved basis. Air conditioning savings generally are found to have more *value* in the context of an integrated analysis than lighting technologies, since air conditioner use is mainly coincident with a region's summer peak-load season, and the avoided capacity value *per kilowatt-hour saved* varies inversely with the hours of use of the appliance or technology. This is illustrated in the following example.

If a utility's avoided costs are $40 per kilowatt per year for load and 5 cents per kilowatt-hour for energy, the benefits to society can be considered for the following two measures: an efficient air conditioner and a new light bulb. The air conditioner saves 1 kW of power but operates only 1,000 hours per year. Its annual load and energy savings value is 40*1 + 0.05*1,000 = $90 per year, which represents $40 for load and $50 for energy. This represents 90/1,000, or 9 cents per kWh saved. The new light bulb operates 6,000 hours per year, saves 40 watts (or 0.04*6,000 = 240 kWh per year), and thus saves 0.04*40 = $1.60 per year of avoided load and 240*0.05 = $12 per year of avoided energy, or $13.60 per year, but only 13.6*100/240 = 5.67 cents per kWh (c/kWh). Thus, the light bulb (5.67 c/kWh) is much less valuable than the air conditioner (9 c/kWh), in terms of avoided load and energy per kilowatt-hour saved. The difference between the two cases lies in the division of the total impacts by kilowatt-hour saved. Because the load benefit is a quotient with kilowatt-hours in the denominator, high benefit values will be attributed to measures with low annual utilization but high coincident load effects, like the air conditioner.

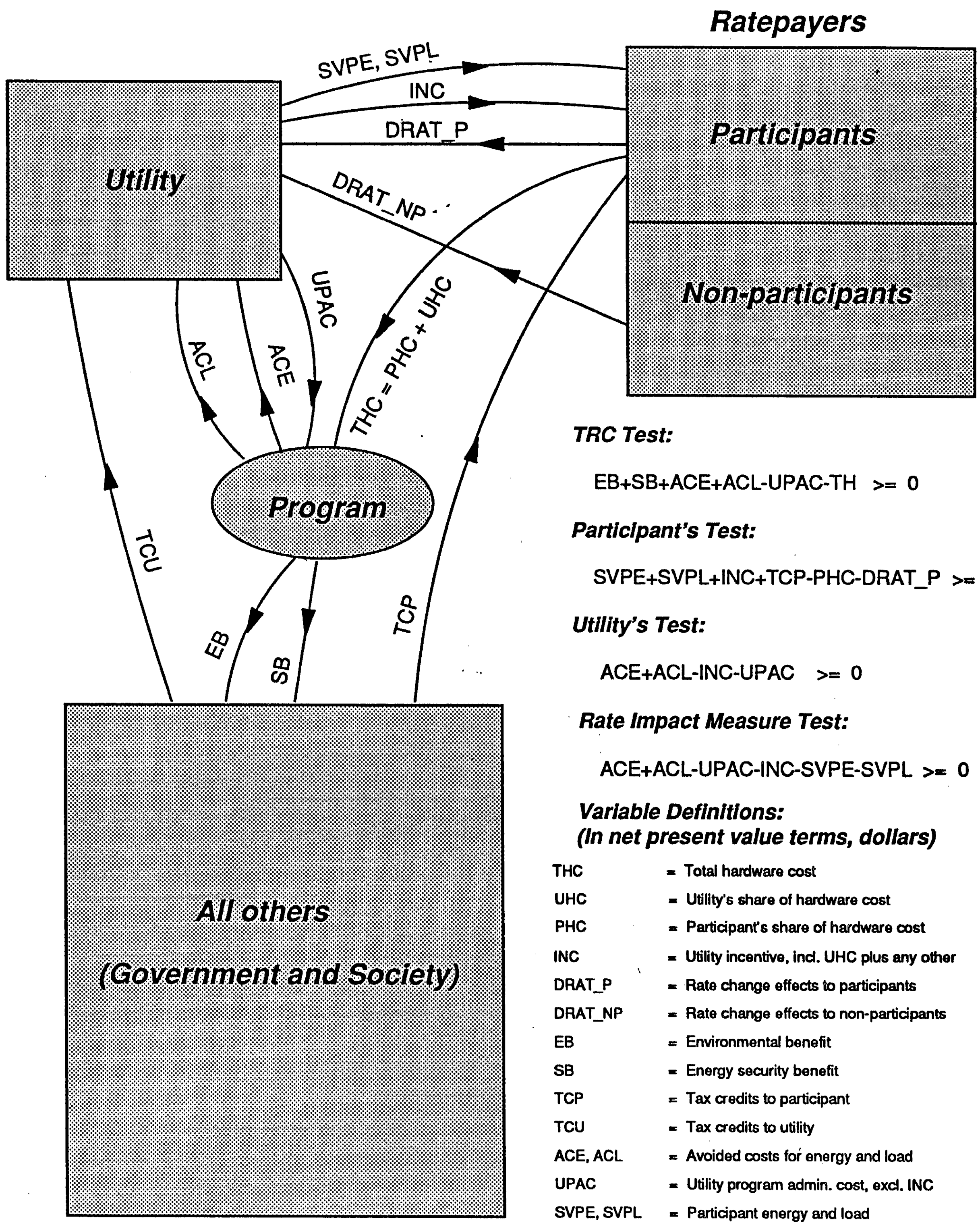
In addition to load savings effects, if the analysis is to include environmental benefits, future *avoided* emission rates of electric utility plants must be estimated. This is often complicated by emission rates that may be changing, as was the case in the District region, due to recent regulations. This is especially true of controls on NO_x.

Many measures of relative merit have been used in published DSM/conservation studies, such as the TRC societal cost/benefit test, which includes all externalities, such as emissions damage avoidance and energy supply security, the Participant's Test, the Utility Test, and the Ratepayer's Impact Test. The major cash and cost elements involved in these tests are shown in Figure III-2. In addition to these tests, it is useful to calculate the CSE, the DSM technology buyer's simple payback (first-year cost divided by first-year energy savings) for the measure, and the utility's avoided cost (the value to the utility of foregone delivery) of energy and load.

The major "first pass" selection test commonly applied for technology impact studies is the TRC/societal test, which depends on the assumed social discount rate, emissions damage cost estimates, marginal emission rates, marginal energy costs, and marginal power (load) costs. This is the test that was adopted for this study. The methodology employed for the TRC tests are described in detail in Appendix C.

Once the technology has passed the "hurdle rate" set for the TRC test and ranked by cost of saved energy, participant simple payback, or TRC, the measures may be

Figure III-2 DSM Measure Benefit/Cost Structure



TRC Test:

EB+SB+ACE+ACL-UPAC-TH >= 0

Participant's Test:

SVPE+SVPL+INC+TCP-PHC-DRAT_P >= 0

Utility's Test:

ACE+ACL-INC-UPAC >= 0

Rate Impact Measure Test:

ACE+ACL-UPAC-INC-SVPE-SVPL >= 0

Variable Definitions:
(In net present value terms, dollars)

THC	= Total hardware cost
UHC	= Utility's share of hardware cost
PHC	= Participant's share of hardware cost
INC	= Utility incentive, incl. UHC plus any other
DRAT_P	= Rate change effects to participants
DRAT_NP	= Rate change effects to non-participants
EB	= Environmental benefit
SB	= Energy security benefit
TCP	= Tax credits to participant
TCU	= Tax credits to utility
ACE, ACL	= Avoided costs for energy and load
UPAC	= Utility program admin. cost, excl. INC
SVPE, SVPL	= Participant energy and load savings, at old rate

aggregated into natural competitive classes, thus forming the *energy reduction supply curves* in order of decreasing benefit. For the District analysis, the measures were ranked by increasing TRC to form the supply curves, but any measure of merit could have been used.

F. DISCOUNT RATES

As discussed in the previous section, one of the goals of this project was to investigate, along with the impact of technologies, the effects that assuming a low social discount rate would have on the results. The low rate of discount would have the effect of showing a high benefit for virtually all measures considered due to the higher value placed on future avoided energy, load, and emissions damage using the lower discount rate.

A pivotal question was to characterize the concept of "low" in these terms. The choice of which discount rate to use for public projects is politically sensitive, bordering on philosophical. How should people value consumption in the present versus conserving energy for future generations? After an extensive review of the literature of discount rates and their application to policy analysis, the rates shown in Table III-4 were selected for the project scenarios. The baseline cases were assumed to use a high real discount rate of 10 percent for TRC technology selection, while both of the DSM/conservation scenarios used a 2 percent real discount rate, which appears to fall at the low end of the scale in terms of academic discussion of the subject. The participant rates were specified for use in the models' market penetration algorithms, if required. The difference between real and nominal rates in the table is a constant 4.13 percent, which is the 1982 to 1991 average inflation rate.

Table III-4
Study Discount Rates

Scenario	Group	Nominal Rate (%)	Real Rate (%)
Incentives and Technology Forcing Scenarios	Participants	14.13	10
	Utility	10.13	6
	Society	6.13	2
Frozen Efficiency and Market Potential Scenarios	Participants	39.13	35
	Utility	10.13	6
	Society	14.13	10

G. MARKET PENETRATION AND DIFFUSION METHODOLOGY

Estimating long-term market penetration of measures and the rate at which that penetration is attained are major DSM analysis issues. This study used two separate, but similar, methodologies for the market penetration estimates: "S-curve" market penetration/diffusion spreadsheet algorithms for California and "multinomial logit" consumer choice methods built into the ENERGY2020 model for Vermont. Both of these related market penetration methods have been widely used for estimating conservation and inter-fuel substitution in energy market analysis models since the first energy crisis (1973). They are described in detail in Chapter IV and Appendix C.

CHAPTER IV
METHODOLOGY

A. OVERVIEW

Three separate and distinct methodological approaches were used for the study:

- A new spreadsheet model developed by Pechan for the project to investigate the residential and commercial sector DSM potential in the Southern California region;
- For the Southern California industrial sector, the Long-Term Industrial Energy Forecasting (LIEF) model, an existing public-domain econometric system developed at Argonne National Laboratories, which was adapted and utilized; and
- For Vermont, the ENERGY2020 integrated energy model, coupled with a macroeconomic system.

These methodologies are discussed in more detail below.

B. THE CALIFORNIA SOUTH COAST RESIDENTIAL/COMMERCIAL MODEL

1. Conceptual Approach

This section presents the methodology underlying the model developed by Pechan for the District. Additional details of some of the individual analytic steps of the model are further explained in the appendices.

While the analyses for the California residential and commercial sectors were performed using entirely separate computer structures and files, the underlying modeling system architecture and the basic distinctive algorithms used for each were essentially identical. For this reason, and to avoid unnecessary duplication of descriptive material, both sectors are described below as if they were a single model. The major difference between the application of the model to the residential sector, as opposed to the commercial sector, was in the data development for stock and energy usage; residential DSM analysis is based on stock stipulated in terms of number of households and total annual energy use, whereas commercial building stock data is organized in terms of square footage by building usage class (e.g., large offices, restaurants, schools). The energy use parameters were consequently developed in terms of annual energy use per square foot of stock (the EUI) for the building class.

The framework for the methodology of the residential/commercial model is the concept of an *energy service class supply curve*. Such curves generally plot the marginal energy reduction, or savings, versus some measure of the technology's relative merit, such as its marginal cost, in the form of a *rate* like the CSE or its TRC ratio. The supply curves are developed for each sector and generic energy end use, herein denoted an energy service class (ESC). For instance, the residential water heating energy service class would include all technologies aimed at saving energy associated with providing heated water at residences, including water heaters, heater tank wraps, and low-flow showerheads. Figure IV-1 shows an example of such a curve. The energy use intensities are rates of energy use from which UECs may be calculated, based on square footage or light intensity, and must be estimable for each sector and ESC in the geographic/regulatory study area. This classification scheme is used to predict energy savings by calculating penetration rates of each of the technologies within the ESC, and adding the expected market penetration and resulting incremental energy savings of each technology. The methodology employs several basic analytic steps:

- supply curve definition (specifying technologies for each sector/ESC), which includes development of ESC-specific data such as total UECs (and/or EUIs), stock (e.g., households), and applicability factors (e.g., percent with space cooling);

- development of technology-specific data, including measure costs, energy and peak-load savings, applicability and feasibility fractions, current saturation, and expected trends in standards or regulations;

- technology screening for benefit/cost;

- estimation of market penetration; and

- running the model and presenting the results.

These steps are discussed below.

2. *Supply Curve Definition*

Data on technologies, stocks, saturation, and estimates of growth and demolition for the District model were received from SCE, LADWP, the three municipal utility systems, and SCG. These data, developed by the utilities with assistance from various contractors (such as Xenergy, LBL, American Council for an Energy-Efficient Economy (ACEEE), and others), were incorporated into the spreadsheet model that was developed for the project.

Each demand sector (residential, commercial, and industrial) represents a separate but similar submodel. Within each sector, applicable technologies are grouped into natural ESCs. These are further divided into two subclassifications: weather-sensitive (insulation, HVAC, infiltration) versus non-weather-sensitive measures (appliances, lighting, water heating), and the applicability of the ESC to either existing or new stock. Table IV-1 shows a fragment of the residential energy service supply curves that result from this classification scheme. In the table, individual supply curves are separated by horizontal lines.

Figure IV-1 Sample California/District Model Energy Conservation Supply Curve

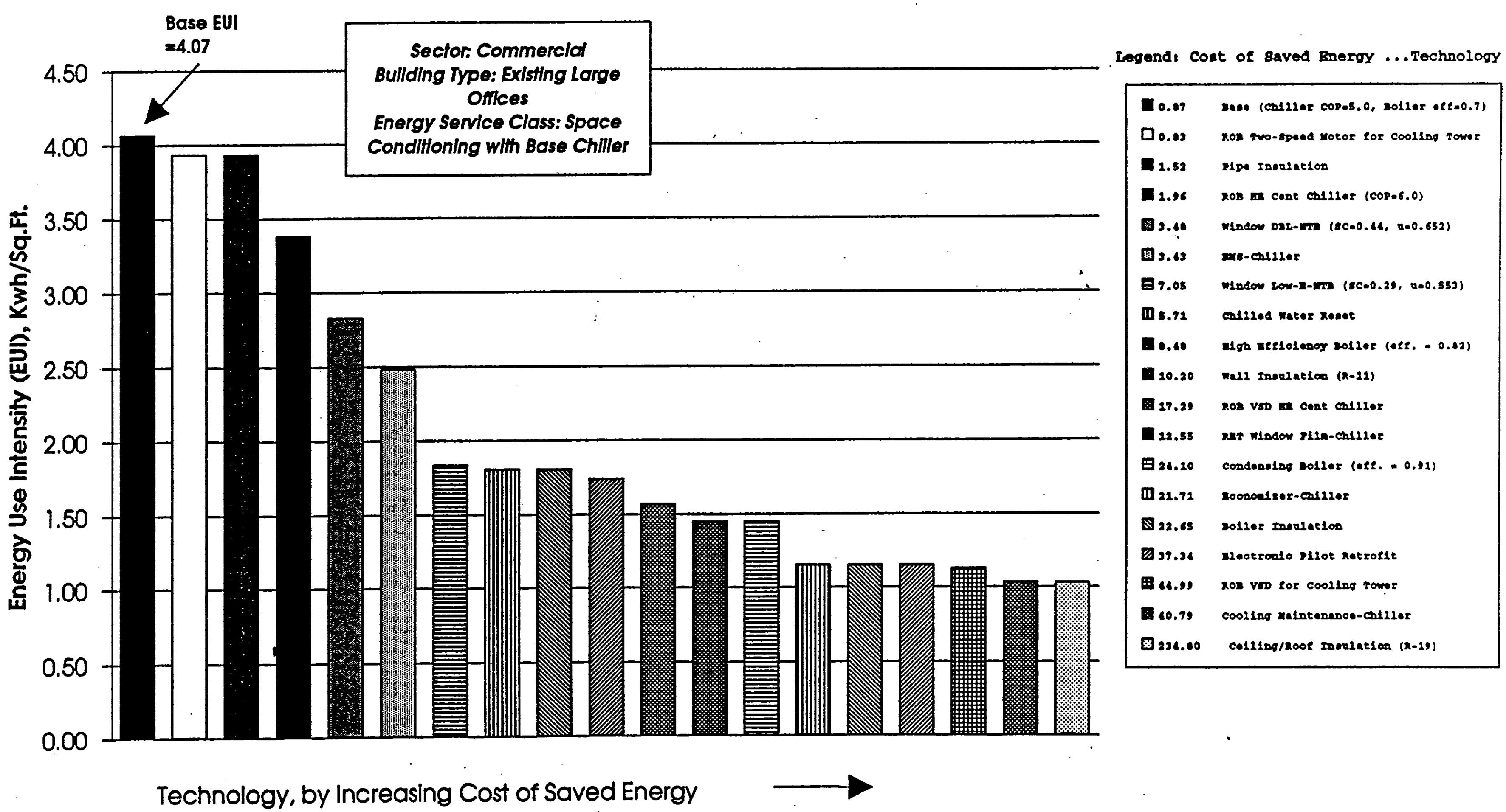


Table IV-1
Energy Service Supply Curve Classification Scheme

Weather-Sensitive (W), or Appliance (A)	Existing/New	Supply Curve Energy Service Class Code	Technology
W	E	CENT HVAC	Base CA (SEER=10,AFUE=0.78)
W	E	CENT HVAC	Improved CA, SEER=12.4
W	E	CENT HVAC	Ceiling insulation (R-4.9 to R-19)
W	N	CENT HVAC	Base CA (SEER=10,AFUE=0.78)
W	N	CENT HVAC	Indirect/direct evap cooling (SEER=25)
W	N	CENT HVAC	Wall insulation (R-13 to R-19)
A	E	MD REF	Baseline manual defrost refrigerator
A	E	MD REF	High-efficiency man defrost ref.
A	E	EL COOK	Base electric cooking
A	E	EL COOK	High-efficiency oven
A	E	EL COOK	Bi-radiant oven
A	E	LIGHT	Base incandescent lighting-75 W
A	E	LIGHT	Halogen-IR 55 W
A	E	LIGHT	Compact fluorescent-18 W
A	E	EL DHW	Base electric direct hot water heater (EF=0.864)
A	E	EL DHW	High-efficiency showerheads
A	E	EL DWH	Heat pump water heater
A	E	EL DWH	Solar water heater
A	N	GAS DWH	Base gas DHW heater EF=0.54
A	N	GAS DHW	Pipe insulation
A	N	GAS DHW	Hot water saver
A	N	GAS DHW	Super efficient DHW (EF=0.71)

The technology list for each curve begins with the base technology for the ESC, which is a prototype of the existing units for retrofit services, but the most common technology for new stock services. Then, all technologies applicable to the class are added to the curve. The technologies may occur in several classes without double-counting, since the UECs and/or stocks of each class are defined to be mutually exclusive in terms of total energy use.

3. Technology Screening

The first calculation step performed by the spreadsheet model is to develop a screening test for the technologies to gauge their relative net benefit. Two such measures are typically calculated for DSM analysis: the CSE and the TRC. Whereas CSE was calculated in the California spreadsheets, it was not used as the primary ranking measure. Instead, the societal version of the TRC test of the California Standard Practice Manual was used as the primary technology-ranking parameter. When used in this document, the mnemonic "TRC" indicates the *societal* version of the TRC test, which includes avoided environmental damage as a benefit. In this analysis, emissions damage was expressed in terms of avoided CO_2 and NO_x emissions only. Other pollutants were considered to be of lesser impact. The CSE and TRC tests are defined in the next sections.

a. The Cost of Saved Energy

Calculation of the CSE for a technology within an ESC is relatively simple in most cases. The CSE may be calculated either as a quotient of net present values or of annualized costs. In the annualized form, which is the way it was treated for California, it is the annualized incremental cost of the technology, divided by the annual energy savings in energy units (kWh, therms, or MMBtu). If the measure affects both natural gas and electricity, like heat pumps, then the CSE *must* be calculated in terms of \$/MMBtu. In this case, electricity savings are expressed in terms of MMBtu of primary heat used by the generating station, and a nominal heat rate must be used in conjunction with an estimate of transmission and distribution (T&D) losses. For California, an estimate of 11,000 Btu/kWh (higher than the average heat rate for units in Southern California), was used to essentially capture both T&D and generation efficiency losses. Since the cost of the measure is annualized by multiplying by a capital recovery factor, CSE is dependent on the assumed discount rate. Equation 1 shows the method used for this calculation for the California region.

$$CSE_i = \frac{\Delta C_i * CRFAC(d,ML_i)}{\left[\frac{\Delta ES_i * 11000}{10^6} + \frac{\Delta GS_i}{10}\right]}; \qquad (1)$$

$$CRFAC(d,ML_i) = \left[\frac{d}{1-(1+d)^{-ML_i}}\right]$$

where:

CSE_i	=	cost of saved energy for DSM measure i, \$/MMBtu
ΔC_i	=	incremental cost of i in dollars
ΔES_i	=	marginal electricity savings of DSM measure (kWh/year)
ΔGS_i	=	marginal gas savings of DSM measure (therms/year)
ML_i	=	measure life in years
d	=	real discount rate (2 percent and 10 percent for this study)
$CRFAC(d,ML_i)$	=	capital recovery factor, using discount rate d and measure life ML_i

If the measure's energy savings is expected to deteriorate over time, the (declining) series of energy savings should be forecast for the life of the technology, a net present value of savings calculated, and this value annualized by multiplying it by CRFAC.

b. The Total Resource Cost Test

The TRC test is a more inclusive order of merit methodology than CSE. There are two reasons for calculating TRCs instead of simply relying on CSE. First, to select technologies that will qualify under established California Public Utilities Commission (PUC) guidelines for inclusion in utility DSM programs, and second, to re-order the measures within each supply curve, which is especially important if the scenario or project guidelines include total *elimination* of non-TRC-passing technologies.

The TRCs may be calculated either as dollar values representing net benefit minus cost, or as dimensionless benefit/cost ratios, at the discretion of the analyst. The latter was chosen for the spreadsheet and this analysis. The California Standard Practice Manual also defines three other tests which are sometimes used to screen technologies: the Participant (P) test, the Utility (U) test, and the Rate Impact Measure (RIM) test. It has been demonstrated mathematically, however, that any technology that passes the TRC will also pass the utility test and that for any technology that passes TRC, it is possible to develop an incentive plan that will pass both the Participant and RIM tests. Thus, the TRC test is undoubtedly the most comprehensive; its use has therefore become common practice in DSM analysis.

Major issues remain regarding the discount rates that should be applied, both in terms of the rate to use for the TRC test and whether the same rate may be assumed for the other tests. A discussion of these rates is included in Appendix A.

As discussed, the California spreadsheet uses TRC as its major technology screening test, using benefit/cost ratio instead of net benefit. The TRCs were calculated as a ratio of present values, as shown in the following equation:

$$TRC_i = \frac{\left[\Delta ES_i * \left(ACKWH_i + \left(\frac{SPSF_i}{SPH} \right) * ACKW_i \right) + \Delta GS_i * ACTHM_i \right]}{CRFAC(d,ML_i) * \Delta C_i} \qquad (2)$$

where:

TRC_i	=	total resource cost for measure i
ΔES_i	=	marginal electricity savings of DSM measure (kWh/year)
$ACKWH_i$	=	avoided cost of electricity including environmental externality costs ($/kWh)
$SPSF_i$	=	system peak savings factor (from load shape data)
SPH	=	system peak hours per year (540 hrs/yr for SCE)
$ACKW_i$	=	annualized avoided cost of system peak power capacity ($/kW-yr)
ΔGS_i	=	marginal gas savings of DSM measure (therms/year)
$ACTHM_i$	=	avoided cost of gas including environmental externalities ($/therm)
$CRFAC(d,ML_i)$	=	capital recovery factor (see Equation 1)
d	=	real discount rate (2 percent and 10 percent for this study)
ML_i	=	life in years, for measure i
ΔC_i	=	incremental cost of DSM measure i

Below is an example of this calculation, considering the following measure:

The measure is to retrofit R-19 ceiling insulation[3], assuming a base of R-4.9 in the existing residential, single-family space conditioning ESC. It decreases average electricity usage by 215 kWh and natural gas usage by 71 therms per year, and the incremental cost of the extra insulation is $464. The measure has an assumed life of 20 years, and the effective summer peak-load factor was 0.64 for the peak period of 540 hours in duration. For TRC calculation, the societal discount rate is assumed to be a 2 percent real discount.

Utility and societal damage avoided costs (including credits for avoided NO_x and CO_2 emissions) were calculated to be as follows:

[3]The "R" value is thermal resistance, a measure of the resistance of insulation material to heat flow through it. For a more complete description see Appendix F.

ACKWH	=	0.062 \$kWh
ACKW	=	52.440 \$/kW
ACTHM	=	0.402 \$/therm

The TRC is then calculated using Equation 2 in the following manner:

$$TRC = (\Delta ES * (0.062 + (0.64/540) * 52.44) + \Delta GS * .402)/(\Delta C * CRFAC)$$

where:

TRC = 1.94 in dimensionless benefit/cost ratio units. This value easily "passes" the 1.0 or lower threshold of the scenarios

ΔES = 215 kWh

ΔGS = 71 therms

CRFAC = $0.0612 = 0.02/(1 - (1.02)^{-20})$

The $0.02/(1-(1.02)^{-20}) = 0.0612$ multiplier in the denominator of the TRC calculation is the capital recovery factor, defined in Equation 1. Thus, both the benefits (avoided costs) in the numerator and the measure costs (in the denominator) of the TRC calculation are annualized, with benefits annualized over a 20-year assumed utility (and societal) planning horizon and measure costs annualized over the measure life. Whereas these periods were the same for this example, in general this is not the case; annualizing avoids the problem of discounting future measure repurchases, should measure life be less than the utility planning horizon.

After the TRCs have been calculated, the technologies within each ESC are ranked in terms of marginal cost/benefit, and the net incremental costs and measure energy savings calculated for each successive measure within a class. This step finalizes the development of the ESC supply curves.

4. *Market Penetration Calculations*

Market penetration rates are calculated for each step on the supply curves. This involves estimating each technology's long-run market share, the expected year-to-year adoption, or "diffusion," rate expected, and the stock that is expected to adopt the technologies within the supply curve's ESC over time -- either as replacements or new additions. These steps are discussed below.

a. *Estimating Long-Run Market Share*

The market share calculation for a technology begins by calculating the simple payback represented by the ratio of first year costs to annual expected energy savings. Simple payback has units of *years* and is calculated using Equation 3.

$$SPB_i = \frac{\Delta \$C_i}{\Delta \$E_i} \tag{3}$$

where:

SPB_i	=	simple payback for measure i
$\Delta\$C_i$	=	incremental cost attributed to the measure within the energy service class supply curve (Note: this cost includes the discounting effects of any incentive, but does not include DSM program administrative costs, since this is the cost to the customer.)
$\Delta\$E_i$	=	annual energy savings in dollars

Simple payback is proportional to the incremental cost of a DSM measure, including the effects of utility rebate programs.

Once the simple payback for the technology is known, the long-run market share is calculated from the S-shaped market penetration curves, using various shape parameters for each sector and energy service class. This is performed using the following formula:

$$LRMS_i = \frac{1}{\left[1 + (AA_i * SPB_i)^{BB_i}\right]} \tag{4}$$

where:

$LRMS_i$	=	long-run market share for measure i
AA_i	=	market penetration coefficient that varies as a function of the type of appliance or end use
SPB_i	=	simple payback for the measure
BB_i	=	market penetration coefficient that varies as a function of the type of appliance or end use

b. Estimating Diffusion

The time rate of market penetration, or market diffusion, accounts for the time delays in attainment of the long-term market share expected for the DSM measure. It is developed as a time series of market share fractions, approaching the long-run market share over time. The final time series is calculated using Equation 5, as shown below:

$$MD_i(t) = \left[\frac{1+SS_i}{\left(1+(1/SS_i)*e^{-RR_i*t}\right)}\right] - SS_i \tag{5}$$

where:

$MD_i(t)$ = market diffusion share for measure i, year t

SS_i = market diffusion curve shape coefficient (e.g. 0.1 was assumed for the residential sector)

RR_i = market diffusion rate coefficient, calculated from an assumed value of SS_i, the calculated long-run market share, and an assumed "years to attain" value, MX, using the equation below. Values of RR_i are typically found to be in the 0.2 to 0.7 range.

$$RR_i = \frac{-\ln\left(\frac{SS_i*(1 - LRMS_i)}{(SS_i + LRMS_i)}\right)}{MX} \tag{6}$$

where:

RR_i = market diffusion rate coefficient for measure i

$LRMS_i$ = long-term market share (defined above in Equation 4)

MX = years to attain long-run market share. A diffusion modeling parameter, assumed to be 12 years for the study.

c. *Estimating Cumulative Stock for Adoption*

Cumulative stock available for adoption for a given energy service class is developed from historic and forecast building and energy use using equipment stocks, current market saturation levels, and UEC for the base technology of the ESC. To these stock/UEC data are added numerous adjustment/estimating factors affecting the applicability and feasibility of the technology to the stock, to account for initial market penetration, and the feasibility of the measure within the potential market. For example, a *measure feasibility factor* is used to adjust stock data for residential markets to represent the fact that floor insulation will only be applicable to houses with crawl spaces, rather than with slabs or (heated) basements. This section discusses the implementation of these stock, saturation, and energy use adjustments within the California model.

The total energy use (TEU_j) for a given energy service class within a given end-use sector, such as commercial or residential[4], is calculated for the base year and each succeeding year t of the forecast, as in Equation 7:

$$TEU_j(t) = UEC_j * N_j(t) * T24_j * (UH_j * AF_j) \tag{7}$$

[4]To simplify the presentation, subscripts are omitted for measure end-use competitive class or building type -- subclass specifications that are carried in the spreadsheet.

where:

TEU = total energy use

j = energy service class index (sector index omitted)

t = year of forecast period

UEC_j = unit energy consumption of the energy service class (kWh or therms or both)

$N_j(t)$ = stock of households or square feet for a given end use at beginning of year t. For existing vintages, $N_i(t)$ goes down as a function of the demolition rate; for new vintages $N_i(t)$ goes up as a function of the growth rate.

$T24_j$ = Title 24 factor used to adjust the UEC by improvements in efficiency resulting from building or appliance standards for the entire ESC

UH_j = units per household factor is used to account for the fraction of the total households or square feet that contain the given energy service

AF_j = applicability factor for the base case is typically 1 unless the end use only applies to a subset of the total households or square feet of floor space

For the base case, the units per household and applicability factors are usually folded into one number. Total energy savings (*TES_{ij}*) for each DSM measure i within the supply curve ESC j are calculated for each end use and building type using Equation 8:

$$TES_{ij}(t) = TEU_j(t) * MT24_i * MAF_i * MNC_i * MAA_i(t) * MD_i(t) \qquad (8)$$

where:

TES = total energy savings

i = measure index

j = supply curve (ESC) index

t = year of forecast period

$TEU_j(t)$ = total energy use for the ESC, from equation 7 (kWh or therms or both)

$MT24_i$ = measure-specific Title 24 factor used to adjust the DSM measure savings estimate by Title 24 building standards or appliance standards. For example, an improvement of a central A/C system to 11.0 SEER was given a MT24 value of 0.82, to account for the expectation that 18 percent of the measure savings was already destined to be mandated by Title 24 and/or NAECA.

MAF_i = measure applicability factor, which is the fraction of the stock for which the measure applies

MNC_i = measure not complete factor, accounts for the number of units left to retrofit or replace (this equals 1 minus the saturation rate; e.g., if 25 percent of ceilings have been insulated, then the not complete factor is 1-.25=.75)

MF_i = measure feasibility factor, accounts for the percent of buildings or square feet that are feasible for the given measure (e.g., evaporative coolers will not apply to high humidity areas and are given an MF value of 0.5 in the District model)

MAA_i = measure cumulative annual stock for adoption availability factor (defined in Equation 9)

$MD_i(t)$ = measure market diffusion factor for year t, defined in Equation 5

The measure annual availability (MAA_i) factor is the fraction of stock (generally households or commercial/industrial square feet) that have made choices in the ESC (for new additions, retrofit, or replacement on burnout) prior to and including the current year. This factor is calculated to provide a running total of the candidate stock that has already made a selection, and is approximated using the following "exponential decay" equation:

$$MAA_i(t) = 1 - e^{-\left(\frac{(1 + ret_i * rob_i)}{ML_i}\right) * t} \tag{9}$$

where:

$MAA_i(t)$ = measure annual availability for measure i

ret_i = fraction of the replace on burnout rate ($1/ML_i$) assumed to retrofit the measure prior to burnout in any year (ret_i is assumed to be 0.5 for the project)

rob_i = replace on burnout toggle (yes = 1, no = 0)

ML_i = measure life in years

t = time in years

e = natural logarithm base

5. *Mathematical Representation of Scenarios*

The Pechan spreadsheet model has a number of parametric "handles" that can be used to assess the impact of utility DSM measures and regulatory policies. The two policies examined in this study are the 100 percent Utility Buy-Down and Technology Forcing. The 100 percent Utility Buy-Down scenario is modeled by allowing a rebate of 100 percent of the incremental cost of a DSM measure if, and only if, TRC $\geq$ 1.0. Otherwise, no rebate is provided. From a consumer perspective, measures with TRC $\geq$ 1.0 have a simple payback of zero and therefore have a long-term market share of 1. These measures will get adopted with greater market diffusion than measures receiving no rebate. The model does provide for savings to be accounted for measures with TRC < 1, using Equations 2 through 9. However, measures having no rebate will diffuse into the market at a much slower rate, depending on their respective simple paybacks.

The Technology Forcing scenario is modeled by allowing for a lower TRC "hurdle rate" of 0.7. This scenario uses the same methodology as the 100 percent Utility Buy-Down. Under this scenario, more measures will make the cutoff, since any measure with a TRC $\geq$ 0.7 receives a 100 percent incremental rebate.

6. *Running the Model*

The model's three sets of major driving variables are as follows: (1) the list of allowable technologies in the ESCs and their costs and energy/load reductions and related applicability factors, (2) scenario-related modifications to participant cost effects, such as utility rebates and/or golden carrot cost reductions, which affect the simple payback, and hence the long-term market share and resulting total energy savings, and (3) modifications to the parameters that affect the TRC test, such as environmental damage cost or the assumed discount rate.

7. *Conservation Supply Curve Spreadsheet Format*

Developing the model data elements into a format to provide ESC-specific technology selection for each scenario is itself an important task. The data elements include measure cost, electricity and natural gas savings, the primary determinants of TRC and simple payback, and the adjustment (not complete, standards, feasible, and applicable) fractions. Table IV-2 contains examples of the data from several of the District residential supply curves used in the analysis. Not shown are the development of unit stock data, or the final technology selection and impacts calculation processes, which were the next steps in the model.

8. *Final Technology Selection*

The supply-curve representation, with each technology's energy savings and related benefits represented by its incremental addition to the cumulative total benefit of all other technologies on the curve, greatly simplifies the measure adoption/final market share calculation algorithm. This representation essentially eliminates the problem of calculating technology-specific market share based on some measure of competitiveness, with the possibility of double-counting or synergistic effects of measures in the same competitive class. In the District model, no technology is ever eliminated from the market; all technologies are selected, as long as their long-run market share is

Table IV-2
California Residential Measure Supply Curves

Application Existing or New Buildings	Energy Service Class Code	Measure	UEC after adoption: Electricity Kwh/yr	UEC after adoption: Nat. Gas Therms	Savings Fraction: Elec.	Savings Fraction: Gas	TRC Test @ 10% Real	Simple Payback (Years)	CSE Primary $/mmBtu	Measure Incremental Cost ($)	Measure Life (years)	Measure Total Cost ($)	Frac Not Complete	Frac. Feasible	Title 24 Factor	Applicability Factors: Electric	Applicability Factors: Nat. Gas
Existing	CAC	Base CAC (SEER=10, AFUE = 0.78)	980.0	336.0	0.000	0.000	n/a	n/a	n/a	2000	15	2000	1.00	1.00	1.00	0.48	0.94
Existing	CAC	Light Colored Roof (Abs. = 0.2 vs 0.5 Base)	882.0	336.0	0.100	0.000	6296.00	0.0	0.00	0	10	2000	0.75	0.90	1.00	0.48	0.94
Existing	CAC	Vegetation/tree planting	793.8	336.0	0.100	0.000	1.67	5.2	6.81	50	25	2000	0.75	0.75	1.00	0.48	0.94
Existing	CAC	Ceiling insulation (R-4.9 to R-19)	579.5	265.4	0.270	0.210	0.98	7.1	6.95	464	20	2000	0.15	1.00	1.00	0.48	0.94
Existing	CAC	Duct leakage	533.1	233.6	0.080	0.120	0.80	8.3	7.63	200	20	2000	0.20	1.00	1.00	0.48	0.58
Existing	CAC	Window Upgrade (Dbl.)	469.1	196.2	0.120	0.160	0.48	16.2	13.12	475	40	2000	0.90	1.00	1.00	0.48	0.94
Existing	CAC	Window Upgrade (Low-E)	398.8	155.0	0.150	0.210	0.37	21.0	16.98	677	40	2000	0.99	1.00	1.00	0.48	0.94
Existing	CAC	Improved CAC ,SEER=11.9	335.0	155.0	0.160	0.000	0.25	29.0	44.96	200	15	2200	0.90	1.00	0.82	0.48	0.94
Existing	CAC	Whole house residential fans	167.5	155.0	0.500	0.000	0.15	50.3	77.84	909	15	3109	0.90	0.70	1.00	0.48	0.94
Existing	CAC	Wall insulation (R-4 to R-11)	154.1	110.1	0.080	0.290	0.13	47.9	41.23	1358	20	4467	0.70	1.00	1.00	0.48	0.94
Existing	CAC	AC/Furnace maintenance	144.8	99.1	0.060	0.100	0.12	15.8	48.16	120	3	4587	0.30	1.00	1.00	0.48	0.94
Existing	CAC	Indirect/direct evap. cooling (SEER = 25)	68.9	99.1	0.524	0.000	0.07	102.7	159.12	842	15	5429	0.95	0.50	0.82	0.48	0.94
Existing	CAC	Weatherization reduce infiltration	68.9	87.2	0.000	0.120	0.07	42.2	79.90	300	5	5729	0.44	1.00	1.00	0.48	0.94
Existing	CAC	Window Upgrade (Low-E Vinyl)	40.8	82.5	0.408	0.053	0.03	275.5	254.18	1598	40	7327	0.99	1.00	1.00	0.48	0.94
Existing	CAC	Condensing furnace (AFUE = 0.9)	40.8	71.8	0.000	0.130	0.02	354.5	298.83	2275	20	9602	0.99	1.00	1.00	0.48	0.58
Existing	CAC	Improved CAC ,SEER=12.4	39.2	71.8	0.040	0.000	0.01	562.9	871.98	100	15	9702	0.95	1.00	0.82	0.48	0.94
Existing	CAC	Evaporative precooler	36.2	71.8	0.075	0.000	0.01	851.0	1318.19	270	15	9972	0.90	0.50	1.00	0.48	0.94
Existing	CAC	Superefficient AC (VSD, SEER=16.9)	26.8	71.8	0.260	0.000	0.01	1376.1	2131.51	1400	15	11372	1.00	1.00	0.82	0.48	0.94
Existing	CAC	Sunscreen	25.5	71.8	0.050	0.000	0.00	2921.6	5601.98	423	10	11795	0.90	0.70	1.00	0.48	0.94
Existing	RAC	Base RAC (EER=8.7)	465.0	0.0	0.000	0.000	n/a	n/a	n/a	374	15	374	1.00	1.00	1.00	0.21	0.00
Existing	RAC	Improved RAC (SEER=10.2, 0.75 tons)	395.3	0.0	0.150	0.000	1.58	4.6	7.20	35	15	374	0.75	1.00	1.00	0.21	0.00
Existing	RAC	Improved RAC (SEER=12.0, 0.75 tons)	336.0	0.0	0.150	0.000	0.92	8.0	12.34	51	15	374	0.80	1.00	1.00	0.21	0.00
Existing	ELRHT	Base Electric Resistance Heating	2250.0	0.0	0.000	0.000	n/a	n/a	n/a	2500	15	2500	1.00	1.00	1.00	0.03	0.00
Existing	ELRHT	High Eff. heat pump HSPF=8.0 (RET)	967.5	0.0	0.570	0.000	0.73	5.4	8.39	750	15	2500	0.75	1.00	1.00	0.03	0.00
Existing	ELRHT	Condensing furnace (AFUE = 0.9)	96.8	85.0	0.900	0.130	0.04	52.6	297.39	2275	20	4775	1.00	1.00	1.00	0.03	0.00
Existing	CAC	Base CAC (SEER=10.0, AFUE = 0.78)	1375.0	190.0	0.000	0.000	n/a	n/a	n/a	2000	15	2000	1.00	1.00	1.00	0.47	1.00
Existing	CAC	Light Colored Roof (Abs.=0.2 vs. Base=0.5)	1278.8	190.0	0.070	0.000	6184.24	0.0	0.00	0	10	2000	0.75	0.90	1.00	0.47	1.00
Existing	CAC	Vegetation/tree planting	1150.9	190.0	0.100	0.000	2.43	3.6	4.70	50	25	2000	0.75	0.75	1.00	0.47	1.00
Existing	CAC	Duct leakage	1058.8	167.2	0.080	0.120	0.84	8.5	8.56	200	20	2000	0.20	0.70	0.86	0.09	0.20
Existing	CAC	Improved CAC ,SEER=11.9	889.4	167.2	0.160	0.000	0.67	10.9	16.93	200	15	2000	0.85	1.00	1.00	0.47	1.00
Existing	CAC	Window Upgrade (Low-E)	684.8	146.3	0.230	0.125	0.44	19.6	19.15	677	40	2000	0.99	1.00	0.86	0.47	1.00
Existing	CAC	Duct insulation (R-4 to R-8)	664.3	143.4	0.030	0.020	0.30	24.5	26.42	97	20	2097	1.00	1.00	0.86	0.47	1.00
Existing	CAC	Whole house residential fans	332.1	143.4	0.500	0.000	0.29	25.3	39.25	909	15	3006	0.90	0.70	1.00	0.47	1.00
Existing	CAC	Window Upgrade (Dbl.)	312.2	116.1	0.060	0.190	0.29	25.7	19.79	475	40	3006	0.67	1.00	0.86	0.47	1.00
Existing	CAC	Indirect/direct evap. cooling (SEER = 25)	148.6	116.1	0.524	0.000	0.15	47.7	73.82	842	15	3848	1.00	0.50	1.00	0.47	1.00
Existing	CAC	AC/Furnace maintenance	132.3	104.5	0.110	0.100	0.14	13.8	43.18	120	3	3968	0.30	1.00	0.86	0.14	0.30
Existing	CAC	Wall insulation (R-13 to R-19)	125.7	95.1	0.050	0.090	0.09	72.8	64.22	462	20	4430	0.99	1.00	0.86	0.47	1.00
Existing	CAC	Improved CAC ,SEER=12.4	121.2	95.1	0.036	0.000	0.04	206.3	319.60	100	15	4530	0.95	1.00	1.00	0.47	1.00
Existing	CAC	Window Upgrade (Low-E Vinyl)	120.0	83.4	0.010	0.123	0.03	224.2	165.71	1598	40	6128	0.99	1.00	0.86	0.47	1.00
Existing	CAC	Evaporative precooler	114.0	83.4	0.050	0.000	0.02	416.8	645.66	270	15	6398	0.90	0.50	1.00	0.47	1.00
Existing	CAC	Superefficient AC (VSD, SEER=16.9)	84.3	83.4	0.260	0.000	0.02	437.5	677.71	1400	15	7798	1.00	1.00	1.00	0.47	1.00
Existing	CAC	Condensing furnace (AFUE = 0.9)	84.3	72.6	0.000	0.130	0.02	350.8	295.71	2275	20	10073	0.99	1.00	0.86	0.47	0.99
Existing	CAC	Ceiling insulation (R-30 to R-38)	83.2	71.6	0.013	0.013	0.01	451.1	407.86	308	20	10381	0.99	0.95	0.86	0.47	1.00
Existing	RAC	Base RAC (EER=8.7)	390.0	0.0	0.000	0.000	n/a	n/a	n/a	374	15	374	1.00	1.00	1.00	0.05	0.00
Existing	RAC	Improved RAC (SEER=10.2, 0.75 tons)	331.5	0.0	0.150	0.150	1.32	5.5	8.58	35	15	374	0.75	1.00	1.00	0.05	0.00
Existing	RAC	Improved RAC (SEER=12.0, 0.75 tons)	280.8	0.0	0.153	0.153	0.79	9.3	14.43	51	15	374	0.80	1.00	1.00	0.05	0.00
Existing	RFMD	Baseline Refrigerator- man defrost,	739.0	0.0	0.000	0.000	n/a	n/a	n/a	396	20	396	1.00	1.00	0.83	0.19	0.00
Existing	RFMD	High eff, man. defrost refrigerator	539.5	0.0	0.270	0.000	2.98	1.6	2.25	35	20	396	1.00	1.00	0.83	0.19	0.00
Existing	RFMD	Near term, man. defrost refrigerator	269.7	0.0	0.500	0.000	1.63	3.2	4.37	92	20	396	1.00	1.00	0.83	0.19	0.00

Note: UECs are shown for single family homes only.
The technologies were the same for multi-family residences.

Table IV-2 (continued)
California Residential Measure Supply Curves

Application Existing or New Buildings	Energy Service Class Code	Measure	UEC after adoption Electricity Kwh/yr	UEC after adoption Nat. Gas Therms	Savings Fraction Elec	Savings Fraction Gas	TRC Test @ 10% Real	Simple Payback (Years)	CSE Primary $/mmBtu	Measure Incremental Cost ($)	Measure Life (Years)	Measure Total Cost ($)	Frac Not Complete	Frac. Feasible	Title 24 Factor	Applicability Factors Electric	Applicability Factors Nat. Gas
Existing	RFAD	Baseline Refrigerator- auto defrost,	1395.0	0.0	0.000	0.000	n/a	n/a	n/a	522	20	522	1.00	1.00	0.87	0.99	0.00
Existing	RFAD	High eff auto defrost refrigerator	1018.4	0.0	0.270	0.000	3.58	1.4	1.87	55	20	522	1.00	1.00	0.87	0.99	0.00
Existing	RFAD	Near term, auto defrost refrigerator	509.2	0.0	0.500	0.000	1.23	3.9	5.46	217	20	522	1.00	1.00	0.87	0.99	0.00
Existing	RFAD	Refrigerator maintenance	483.7	0.0	0.050	0.000	0.46	10.5	14.49	29	20	522	0.75	0.90	1.00	0.99	0.00
Existing	FRZR	Baseline Freezer - man defrost, AV=26.1	993.0	0.0	0.000	0.000	n/a	n/a	n/a	380	20	380	1.00	1.00	0.74	0.22	0.00
Existing	FRZR	High Eff. freezer, upright, man. defrost	854.0	0.0	0.140	0.000	7.27	0.7	0.92	10	20	380	1.00	1.00	0.74	0.22	0.00
Existing	FRZR	Near term freezer, upright man. defrost	512.4	0.0	0.400	0.000	2.05	2.4	3.26	87	20	380	1.00	1.00	0.74	0.22	0.00
Existing	ELCK	Base Electic Cooking	819.0	0.0	0.000	0.000	n/a	n/a	n/a	584	15	584	1.00	1.00	1.00	0.29	0.00
Existing	ELCK	High eff oven (insulation, seals, reduced mass)	696.2	0.0	0.150	0.000	1.87	2.7	4.20	36	15	584	0.95	1.00	1.00	0.29	0.00
Existing	ELCK	Bi-radiant oven	473.4	0.0	0.320	0.000	1.91	2.7	4.11	64	15	584	0.99	0.90	1.00	0.29	0.00
Existing	ELCK	Cooktop reflector pans	445.0	0.0	0.060	0.000	0.81	6.3	9.69	19	15	584	0.80	0.70	1.00	0.29	0.00
Existing	ELDHW	Base Electric DHW Heater (EF=0.864)	4497.0	0.0	0.000	0.000	n/a	n/a	n/a	150	15	150	1.00	1.00	1.00	0.06	0.00
Existing	ELDHW	High efficiency showerheads	4182.2	0.0	0.070	0.000	14.76	0.3	0.46	10	15	150	0.40	0.95	1.00	0.06	0.00
Existing	ELDHW	Water heater insulation	4056.7	0.0	0.030	0.000	5.88	0.7	1.14	10	15	150	0.50	0.80	1.00	0.06	0.00
Existing	ELDHW	Heat pump water heater	1176.5	0.0	0.710	0.000	1.93	2.3	3.49	700	15	150	0.95	0.95	1.00	0.06	0.00
Existing	ELDHW	Hot water saver	941.2	0.0	0.200	0.000	0.44	9.8	15.24	250	15	400	0.99	0.95	1.00	0.06	0.00
Existing	ELDHW	Solar water heater	207.1	0.0	0.780	0.000	0.12	35.9	55.68	2850	15	3250	0.80	0.75	1.00	0.06	0.00
Existing	ELDWR	Base dishwasher	888.0	0.0	0.000	0.000	n/a	n/a	n/a	300	10	300	1.00	1.00	1.00	0.04	0.00
Existing	ELDWR	High efficiency dishwashers	710.4	0.0	0.200	0.000	2.26	1.6	3.00	30	10	300	0.80	1.00	1.00	0.04	0.00
Existing	ELCWR	Base Clotheswasher	1234.0	0.0	0.000	0.000	n/a	n/a	n/a	380	10	380	1.00	1.00	1.00	0.05	0.00
Existing	ELCWR	High efficiency clotheswashers - Vert. Axis	900.8	0.0	0.270	0.000	3.69	0.9	1.81	34	10	380	0.70	1.00	1.00	0.05	0.00
Existing	ELCWR	High efficiency clotheswashers - Horiz. Axis	333.3	0.0	0.630	0.000	1.29	2.7	5.19	166	10	380	0.95	1.00	1.00	0.05	0.00
Existing	ELCDR	Base Dryer Electric Resistance	982.0	0.0	0.000	0.000	n/a	n/a	n/a	300	10	300	1.00	1.00	1.00	0.27	0.00
Existing	ELCDR	Microwave Dryer	589.2	0.0	0.400	0.000	1.53	2.4	4.52	100	10	300	1.00	1.00	1.00	0.27	0.00
Existing	ELCDR	Heat Pump Dryer-ROB	176.8	0.0	0.700	0.000	0.46	7.9	15.07	350	10	650	1.00	1.00	1.00	0.27	0.00
Existing	LIGHT	Base Incandescent Lighting - 75W	926.0	0.0	0.000	0.000	n/a	n/a	n/a	12	10	12	1.00	1.00	1.00	0.95	0.00
Existing	LIGHT	Halogen-IR - 55W	676.0	0.0	0.270	0.000	5.68	0.6	1.20	17	10	12	0.85	0.40	1.00	0.95	0.00
Existing	LIGHT	Compact fluorescent-18W	213.6	0.0	0.684	0.000	1.41	2.5	4.83	126	10	12	0.95	0.70	1.00	0.95	0.00
Existing	ELPL	Base Pool Pump	2397.0	0.0	0.000	0.000	n/a	n/a	n/a	277	10	277	1.00	1.00	1.00	0.12	0.00
Existing	ELPL	Two-Speed Pool Pump	1558.1	0.0	0.350	0.000	3.18	1.1	2.18	103	10	277	0.95	1.00	1.00	0.12	0.00
Existing	NGDHW	Base Gas DHW Heater EF=0.54	0.0	221.0	0.000	0.000	n/a	n/a	n/a	150	15	150	1.00	1.00	0.94	0.96	0.00
Existing	NGDHW	High efficiency showerheads	0.0	196.7	0.000	0.110	11.26	0.5	0.47	7	15	150	0.40	0.95	0.94	0.96	0.00
Existing	NGDHW	Pipe insulation	0.0	188.8	0.000	0.040	5.83	1.0	0.90	5	15	150	0.85	0.80	1.00	0.96	0.00
Existing	NGDHW	Faucet aerators	0.0	183.2	0.000	0.030	4.72	1.2	1.11	4	15	150	0.70	0.80	1.00	0.96	0.00
Existing	NGDHW	Water heater insulation	0.0	172.2	0.000	0.060	3.66	1.5	1.44	10	15	150	0.13	0.80	0.94	0.96	0.00
Existing	NGDHW	High efficiency DHW (EF = 0.61)	0.0	153.2	0.000	0.110	0.53	10.6	10.00	120	15	150	0.93	1.00	1.00	0.96	0.00
Existing	NGDHW	High efficiency clotheswashers - Vert. Axis	0.0	148.6	0.000	0.030	0.36	12.4	14.44	34	10	184	0.70	1.00	1.00	0.89	0.00
Existing	NGDHW	Hot water saver	0.0	126.3	0.000	0.150	0.30	18.8	17.69	250	15	434	0.95	0.95	1.00	0.96	0.00
Existing	NGDHW	Solar water heater	0.0	63.2	0.000	0.500	0.07	75.4	71.18	2850	15	3284	0.89	0.50	1.00	0.96	0.00
Existing	NGDHW	Super efficiency DHW (EF = 0.71)	0.0	54.3	0.000	0.140	0.07	83.2	78.49	440	15	3724	1.00	1.00	1.00	0.96	0.00
Existing	NGDHW	Heat trap	0.0	53.2	0.000	0.020	0.07	84.7	79.86	55	15	3779	0.80	0.95	1.00	0.96	0.00
Existing	NGDHW	High efficiency clotheswashers - Horiz. Axis	0.0	49.5	0.000	0.070	0.06	74.5	86.99	166	10	3945	0.95	1.00	1.00	0.89	0.00
Existing	NGDHW	Flue damper	0.0	48.0	0.000	0.030	0.04	135.1	127.46	120	15	4065	0.95	0.95	1.00	0.96	0.00
Existing	NGCDR	Base Gas Dryer	0.0	40.0	0.000	0.000	n/a	n/a	n/a	300	10	300	1.00	1.00	1.00	0.64	0.00
Existing	NGCDR	High efficiency dryer	0.0	35.2	0.000	0.120	0.13	34.8	40.69	100	10	400	0.60	1.00	1.00	0.64	0.00
Existing	NGPL	Base Gas Pool Heater (CE = 0.80)	0.0	100.0	0.000	0.000	n/a	n/a	n/a	1600	15	1600	1.00	1.00	1.00	0.08	0.00
Existing	NGPL	Pool cover (plastic bubble)	0.0	50.0	0.000	0.500	1.31	3.4	4.02	103	10	1600	0.20	0.95	1.00	0.08	0.00
Existing	NGPL	Solar Pool heater	0.0	25.0	0.000	0.500	0.02	256.9	299.97	3840	10	5440	0.89	0.50	1.00	0.08	0.00
Existing	NGPL	High efficiency pool heater (CE = 0.97)	0.0	20.5	0.000	0.180	0.01	1114.8	1051.79	3000	15	8440	1.00	1.00	1.00	0.08	0.00

Note: UECs are shown for single family homes only.
The technologies were the same for multi-family residences.

Table IV-2 (continued)
California Residential Measure Supply Curves

Application Existing or New Buildings	Energy Service Class Code	Measure	UEC after adoption		Savings Fraction		TRC Test @ 10% Real	Simple Payback (Years)	CSE Primary $/mmBtu	Measure Incremental Cost ($)	Measure Life (Years)	Measure Total Cost ($)	Frac Not Complete	Frac. Feasible	Title 24 Factor	Applicability Factors	
			Electricity Kwh/Yr	Nat. Gas Therms	Elec	Gas										Electric	Nat. Gas
New	RFMD	Baseline Refrigerator- man defrost,	614.0	0.0	0.000	0.000	n/a	n/a	n/a	396	20	396	1.00	1.00	1.00	0.09	0.00
New	RFMD	High eff, man. defrost refrigerator	448.2	0.0	0.270	0.000	2.48	2.0	2.71	35	20	396	1.00	1.00	1.00	0.09	0.00
New	RFMD	Near term, man. defrost refrigerator	224.1	0.0	0.500	0.000	1.27	3.8	5.26	92	20	396	1.00	1.00	1.00	0.09	0.00
New	RFAD	Baseline Refrigerator- auto defrost,	1118.0	0.0	0.000	0.000	n/a	n/a	n/a	522	20	522	1.00	1.00	1.00	1.09	0.00
New	RFAD	High eff auto defrost refrigerator	816.1	0.0	0.270	0.000	2.87	1.7	2.33	55	20	522	1.00	1.00	1.00	1.09	0.00
New	RFAD	Refrigerator maintenance	775.3	0.0	0.050	0.000	0.74	6.5	9.04	29	20	522	0.75	0.90	1.00	1.09	0.00
New	RFAD	Near term, auto defrost refrigerator	387.7	0.0	0.500	0.000	0.93	5.2	7.17	217	20	522	1.00	1.00	1.00	1.09	0.00
New	FRZR	Baseline Freezer - man defrost, AV=26.1	706.0	0.0	0.000	0.000	n/a	n/a	n/a	380	20	380	1.00	1.00	1.00	0.22	0.00
New	FRZR	High Eff. freezer, upright, man. defrost	607.2	0.0	0.140	0.000	5.17	0.9	1.30	10	20	380	1.00	1.00	1.00	0.22	0.00
New	FRZR	Near term freezer, upright man. defrost	364.3	0.0	0.400	0.000	1.46	3.3	4.59	87	20	380	1.00	1.00	1.00	0.22	0.00
New	ELCK	Base Electric Cooking	808.0	0.0	0.000	0.000	n/a	n/a	n/a	584	15	584	1.00	1.00	1.00	0.33	0.00
New	ELCK	High eff oven (insulation, seals, reduced mass)	686.8	0.0	0.150	0.000	1.84	2.8	4.26	36	15	584	0.95	1.00	1.00	0.33	0.00
New	ELCK	Cooktop reflector pans	645.6	0.0	0.060	0.000	1.17	4.3	6.68	19	15	584	0.80	0.70	1.00	0.33	0.00
New	ELCOO	Bi-radiant oven	439.0	0.0	0.320	0.000	1.77	2.9	4.43	64	15	584	1.00	0.90	1.00	0.33	0.00
New	ELDHW	Base Electric DHW Heater (EF=0.864)	4481.0	0.0	0.000	0.000	n/a	n/a	n/a	150	15	150	1.00	1.00	1.00	0.06	0.00
New	ELDHW	Hot water saver	3584.8	0.0	0.200	0.000	1.68	2.6	4.00	250	15	150	0.99	0.95	1.00	0.06	0.00
New	ELDHW	Heat pump water heater	1039.6	0.0	0.710	0.000	1.70	2.5	3.94	700	15	150	0.95	0.95	1.00	0.06	0.00
New	ELDHW	Solar water heater	228.7	0.0	0.780	0.000	0.13	32.5	50.41	2850	15	3000	0.80	0.75	1.00	0.06	0.00
New	ELDWR	Base Dishwasher	888.0	0.0	0.000	0.000	n/a	n/a	n/a	300	10	300	1.00	1.00	1.00	0.06	0.00
New	ELDWR	High efficiency dishwashers	710.4	0.0	0.200	0.000	2.26	1.6	3.00	30	10	300	0.80	1.00	1.00	0.06	0.00
New	ELCWR	Base Clotheswasher	1234.0	0.0	0.000	0.000	n/a	n/a	n/a	380	10	380	1.00	1.00	1.00	0.06	0.00
New	ELCWR	High efficiency clotheswashers - Vert. Axis	900.8	0.0	0.270	0.000	3.69	0.9	1.81	34	10	380	0.70	1.00	1.00	0.06	0.00
New	ELCWR	High efficiency clotheswashers - Horiz. Axis	333.3	0.0	0.630	0.000	1.29	2.7	5.19	166	10	380	0.95	1.00	1.00	0.06	0.00
New	ELCDR	Base Dryer Electric Resistance	930.0	0.0	0.000	0.000	n/a	n/a	n/a	300	10	300	1.00	1.00	1.00	0.29	0.00
New	ELCDR	Microwave Dryer	558.0	0.0	0.400	0.000	1.44	2.5	4.77	100	10	300	1.00	1.00	1.00	0.29	0.00
New	ELCDR	Heat Pump Dryer-ROB	167.4	0.0	0.700	0.000	0.43	8.3	15.91	350	10	650	1.00	1.00	1.00	0.29	0.00
New	LIGHT	Base Incandescent Lighting - 75W	926.0	0.0	0.000	0.000	n/a	n/a	n/a	12	10	12	1.00	1.00	1.00	0.95	0.00
New	LIGHT	Halogen-IR - 55W	676.0	0.0	0.270	0.000	5.68	0.6	1.20	17	10	12	0.85	0.90	1.00	0.95	0.00
New	LIGHT	Compact fluorescent-18W	213.6	0.0	0.684	0.000	1.41	2.5	4.83	126	10	12	0.95	0.90	1.00	0.95	0.00
New	ELPL	Base Pool Pump	2397.0	0.0	0.000	0.000	n/a	n/a	n/a	277	10	277	0.95	1.00	1.00	0.17	0.00
New	ELPL	Two-Speed Pool Pump	1558.1	0.0	0.350	0.000	3.18	1.1	2.18	103	10	277	0.95	1.00	1.00	0.17	0.00
New	NGDHW	Base Gas DHW Heater EF=0.54	0.0	224.0	0.000	0.000	n/a	n/a	n/a	150	15	150	1.00	1.00	0.93	0.97	0.00
New	NGDHW	Pipe Insulation	0.0	215.0	0.000	0.040	6.64	0.8	0.79	5	15	150	0.85	0.80	0.93	0.97	0.00
New	NGDHW	High efficiency DHW (EF = 0.61)	0.0	191.4	0.000	0.110	0.66	8.5	8.00	120	15	150	0.93	1.00	0.93	0.97	0.00
New	NGDHW	High efficiency clotheswashers - Vert. Axis	0.0	185.6	0.000	0.030	0.45	9.9	11.56	34	10	184	0.70	1.00	0.93	0.90	0.00
New	NGDHW	Hot water saver	0.0	157.8	0.000	0.150	0.37	15.0	14.16	250	15	434	0.95	0.95	0.93	0.97	0.00
New	NGDHW	Solar water heater	0.0	78.9	0.000	0.500	0.09	60.4	56.99	2850	15	3284	0.89	0.50	0.93	0.97	0.00
New	NGDHW	Super efficiency DHW (EF = 0.71)	0.0	67.9	0.000	0.140	0.08	66.6	62.85	440	15	3724	1.00	1.00	0.93	0.97	0.00
New	NGDHW	Heat trap	0.0	66.5	0.000	0.020	0.08	67.8	63.94	55	15	3779	0.80	0.95	0.93	0.97	0.00
New	NGDHW	High efficiency clotheswashers - Horiz. Axis	0.0	61.8	0.000	0.070	0.08	59.6	69.65	166	10	3945	0.95	1.00	0.93	0.90	0.00
New	NGDHW	Flue damper	0.0	60.0	0.000	0.030	0.05	108.2	102.05	120	15	4065	0.95	0.95	0.93	0.97	0.00
New	NGCDR	Base Gas Dryer	0.0	40.0	0.000	0.000	n/a	n/a	n/a	300	10	300	1.00	1.00	1.00	0.64	0.00
New	NGCDR	High efficiency dryer	0.0	35.2	0.000	0.120	0.13	34.8	40.69	100	10	400	0.60	1.00	1.00	0.64	0.00
New	NGPL	Base Gas Pool Heater (CE = 0.80)	0.0	100.0	0.000	0.000	n/a	n/a	n/a	1600	15	1600	1.00	1.00	1.00	0.10	0.00
New	NGPL	Pool cover (plastic bubble)	0.0	50.0	0.000	0.500	1.31	3.4	4.02	103	10	1600	0.20	0.95	1.00	0.10	0.00
New	NGPL	Solar Pool heater	0.0	25.0	0.000	0.500	0.02	256.9	299.97	3840	10	5440	0.89	0.50	1.00	0.10	0.00
New	NGPL	High efficiency pool heater (CE = 0.97)	0.0	20.5	0.000	0.180	0.01	1114.8	1051.79	3000	15	8440	1.00	1.00	1.00	0.10	0.00

Note: UECs are shown for single family homes only.
The technologies were the same for multi-family residences.

calculated to be positive (no mater how small). In an extreme scenario, all of the technologies could be forced to a long-run market share of 1.0, which would correspond to a "technologically feasible" scenario, and over time, would approach the maximum energy savings represented by the combined effects of all of the technologies in the supply curve. Thus, all technologies (or in the supply curve sense, the increments on the curve) are given some market share. No technology is totally eliminated, although it may be passed up for utility rebates for failure to pass TRC. Those that do pass will be given the scenario measure rebates and thus have a shorter payback, a longer long-term market share, and will affect the incremental savings accordingly. Figure IV-2 shows the data development and mathematical processes involved in the District model.

C. THE CALIFORNIA/DISTRICT INDUSTRIAL MODEL

The industrial sector modeling for the District was performed using a public domain model, the LIEF model developed under a DOE contract by Argonne National Laboratories and others. A description of the model is attached as Appendix G. LIEF is a Standard Industrial Classification (SIC) oriented model which balances capital expenditures in energy efficiency against avoided cost of delivering energy and power to the end-use sector. The model was selected for the District for several reasons. While it would have been desirable to find or develop a detailed technology-specific model such as those used for the residential and commercial sectors, the data to support such an effort for the District industrial sector was not available (e.g., lighting, motors and/or space conditioning square footage and EUIs). Most of the industrial sector data available (from the U.S. Departments of Energy and Commerce and the California Energy Commission) were aggregated by SIC classification with limited technology detail.

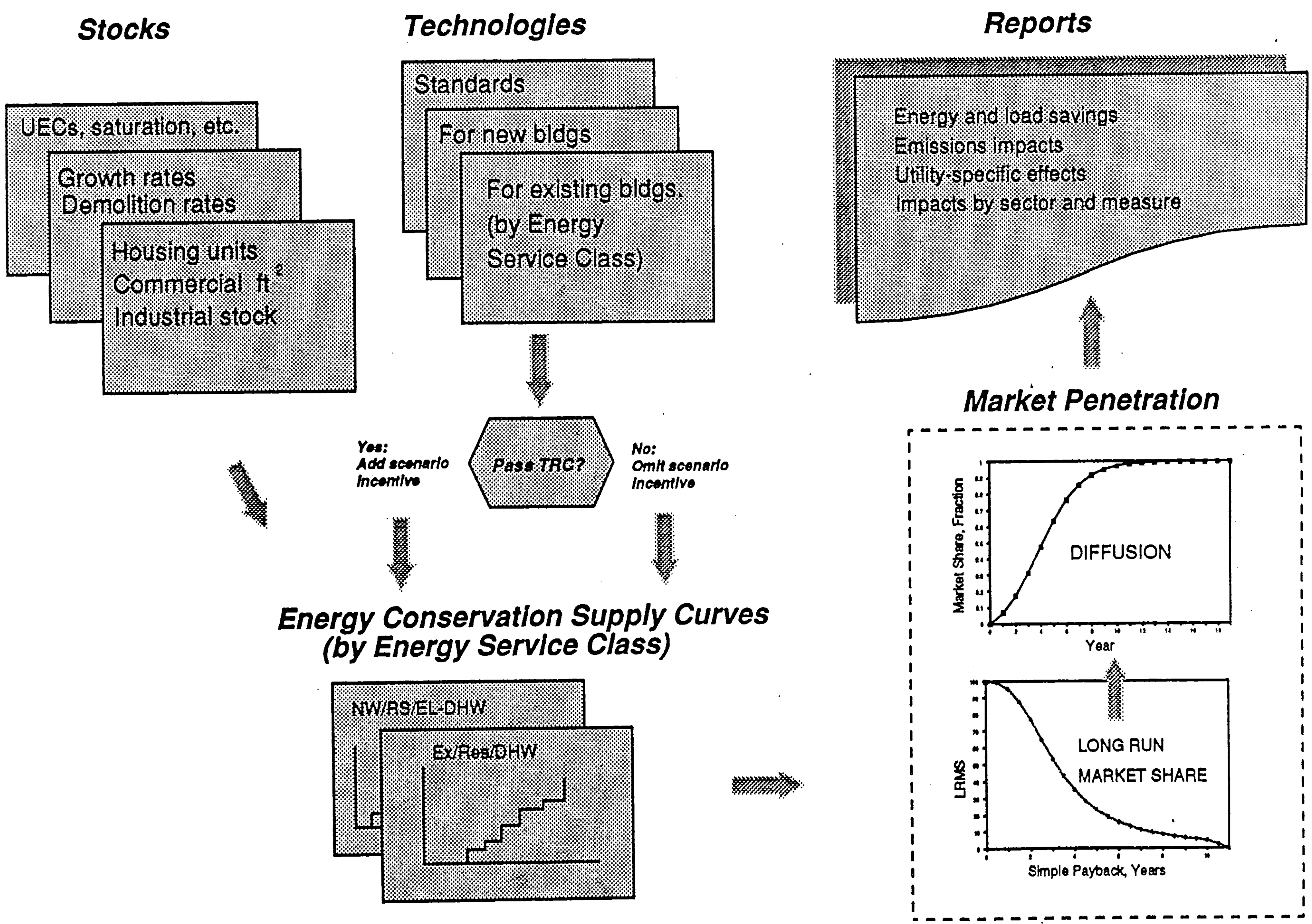
Data to support the LIEF model structure for the District were taken directly from the California Energy Commission Energy Report 1992 (CEC/ER-92) for the six utilities in the area. However, since individual electric utility data were not broken down by SIC class, the five electric utilities' industrial demand was aggregated together and later estimated from the total SIC results by simple prorationing using ER-92 projections of industrial demand.

D. THE VERMONT MODEL

1. *Introduction*

This section discusses the Vermont Department of Public Service application of the ENERGY2020 model for evaluation of the environmental, and energy systems impacts of the case study evaluating demand-side technologies for mitigating global climate change. ENERGY2020 is an integrated planning framework that simulates the energy dynamics of a region under various external and policy conditions (Backus and Amlin, 1987). It is a descriptive policy model that dynamically simulates both historical and future conditions for specified region. ENERGY2020 is an all-fuel energy analysis framework. It normally simulates the supply, prices, and demand for all fuels. These features make it an extremely valuable strategic planning tool. For the purposes of this analysis, however,

Figure IV-2 California/District Residential and Commercial Model Data and Process Flowchart



the model's demand sector was exogenously supplied with alternative energy price and supply forecasts.

A State-level, dynamic macroeconomic model (REMI) is linked to ENERGY2020.

2. Overview of ENERGY2020

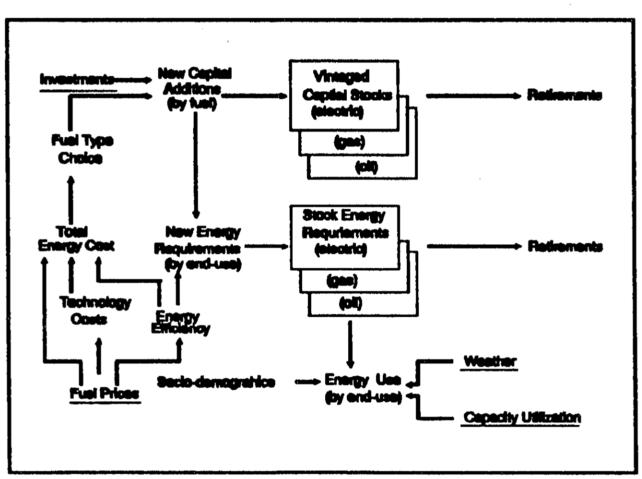
Full implementation of ENERGY2020 requires the specification of three major energy market components: (1) the service area economy, (2) the energy demand, and (3) the region/service area energy supply.

The model represents the regional demand in terms of economic sectors: residential, commercial, and industrial. All the sectors can be further disaggregated. In the version of the model used for this analysis, the economy is disaggregated into 23 separate economic sectors: Residential, Commercial, 2-digit Manufacturing SIC code, Agriculture, and Mining. Within the economic segment, the REMI macroeconomic model dynamically provides detailed, State-level economic information to ENERGY2020. Most importantly, the REMI model provides ENERGY2020 with local inflation rates and local capital investments in new (energy-using) buildings and equipment. ENERGY2020 provides REMI with energy prices and utility construction costs/local expenditures.

Each of the consumer (economic) sectors chooses from a number of alternative fuels (natural gas, liquid petroleum gas [LPG], oil, wood, solar, coal, and electricity) to satisfy specific end uses (space heating, water heating, cooking, drying, refrigeration, lighting, air conditioning, and miscellaneous electromotive). Cogeneration by fuel type can be explicitly simulated in the demand sectors for all economic sectors desired. Changes in energy efficiency are simulated using either measure-by-measure (least cost) or consumer preference approaches. The model allows fuel conversions and fuel switching and models the effects of energy shortages. (Detailed LPG usage simulation was added for this analysis because of its importance to Vermont.)

Figure IV-3 shows an overview of the ENERGY2020 structure configured for use with exogenous fuel cost data.

Figure IV-3 Overview of ENERGY2020 Structure



i. The History of ENERGY2020

ENERGY2020 combines the formalism of engineering and financial modeling with the statistical rigor of economic/econometric models. The demand sector causally extends the approaches taken in the most advanced economic/econometric models for the residential, commercial, and industrial sectors (EPRI, 1982; Jackson et al., 1982; Reister et al., 1982). The supply sector causally extends the approaches used in state-of-the-art production costing and financial models (DFI, 1984; EPRI, 1988). The most important characteristic, however, is the feedback simulation which uses the System Dynamics methodology founded in engineering control theory. The National Electric Reliability Council (NERC) recently noted that the biggest problem with previous analyses was the neglect of price feedback (Nelson et al., 1989).

The current version of the model represents the culmination of a model development process that started in 1976 at Dartmouth College with an early version of the model (FOSSIL1) written in DYNAMO, under primary sponsorship by DOE (Backus et al., 1977).

In 1979, the DOE model was modified and renamed FOSSIL2. This model has been used to formulate national energy policy since President Carter's National Energy Plan II (DOE, 1981). It is currently being used to analyze environmental impacts for the National Energy Strategy Plan.

An advanced causal demand model (DEMAND81) was developed at Purdue University in 1981 for national energy demand policy analysis and was adapted for use at the State level by the Vermont Department of Public Service (Steinhurst, 1984; Backus, 1981). After further development related to regional issues, DEMAND81 became the basis for the demand sector of ENERGY2020.

The first microcomputer-based integrated energy model to use the new demand concepts and a detailed electric supply sector was the Integrated Planning Model (IPM) written in PROMULA (Backus, 1982). The electric utility portion of the model was originally based on the approach that became the CPAM model used at the Bonneville Power Administration (Ford, 1986). After rigorous field and empirical testing, that research evolved into the ENERGY2020 model used for this analysis. Over 350 organizations have a version of ENERGY2020. It is used regularly by many utilities and State agencies, including the Vermont Department of Public Service, the Illinois Department of Energy and Natural Resources, and the Massachusetts Department of Energy Resources. In 1988, the American Public Power Association chose ENERGY2020 as the basis for its "Community-Oriented Model for Planning Least-Cost Energy Alternatives and Technologies" project. The resulting COMPLEAT model has a sophisticated user interface with enhanced capabilities for public power clients. Recently, the California Energy Commission evaluated 26 energy models and selected ENERGY2020 as the best model for analyses for the 3- to 30-year time horizon.

ii. Macroeconomic Simulation

The REMI model is an econometric model that simulates changes in inter-regional trade interactions between Vermont and the rest of the world as costs in Vermont change (Treyz et al., 1981). Businesses and population migrate in and out of the State as economic conditions dictate. Detailed macroeconomic and production calculations determine the use and supply of goods and services in Vermont. Employment and business growth change as local prices and demand change. The REMI model uses the Bureau of Labor Statistics (Department of Commerce) projections for the United States to compare the competitiveness of and rest-of-world demand for Vermont products. (A Cobb-Douglas formulation is used to simulate changes in economic I/O coefficients.)

Calculated economic growth is fed to the ENERGY2020 model to simulate new (energy-using) investments such as homes, factories, stores, equipment, and appliances. In return, ENERGY2020 sends energy prices and energy-related construction expenditures to REMI to simulate the local impacts of energy industry expansion, as well as to capture the change in Vermont business competitiveness from changing energy costs. The use of the REMI macroeconomic model allowed the testing of various regulatory, environmental, development, and conservation policy effects on regional employment and economic growth, for example. No other modeling effort has successfully incorporated this linkage between energy and the local economy.

iii. Energy Demand Simulation

The demand sector of ENERGY2020 represents the service area by disaggregating the three economic sectors -- residential, commercial and industrial -- into subsectors based on energy end use. Multiple end uses (including transportation and feed stocks) and multiple fuels are detailed. As many or as few subsectors can be supported as desired. Cogeneration, fungible demands (fuel switching), municipal resale demands, and power pool resale demands are also determined by the model.

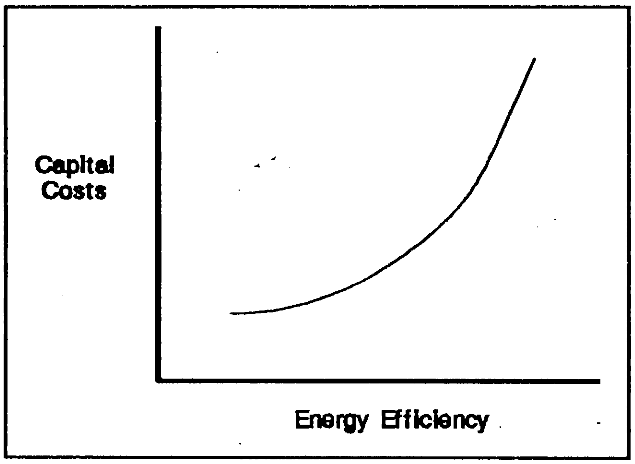
ENERGY2020 assumes that energy demand is a consequence of using capital stock in the production of output. For example, the industrial sector produces goods in factories which require energy for production, the commercial sector requires buildings to provide services, and the residential sector needs housing if it is to provide sustained labor services. These buildings and their occupants require energy for heating, cooling, and electromechanical (appliance) uses.

The amount of energy used in a building is based on the concept of energy efficiencies. The energy efficiency of a house, along with the conversion efficiency of the furnace, determines how much energy is used to provide the desired warmth. The energy efficiency of the house is called the *capital stock energy efficiency*, or "process efficiency." This efficiency is primarily technological (for example, insulation) but can also be associated with control or life-style changes (for example, operating a house or factory with more energy frugality). The furnace efficiency is called the device or thermal efficiency. Thermal efficiency is associated with air conditioning, electromotive devices, furnaces, and appliances.

The model simulates investment in energy using capital (buildings and equipment) from installation to retirement through three age classes or vintages. This capital represents embodied energy requirements that will result in a specified energy demand as the capital is utilized. Based on perceptions of cost and utility, consumers determine which fuel and technology to use for new investments.

In essence, consumers trade off fuel costs for increased efficiency and concomitant increased capital costs as is show in Figure IV-4. These marginal values change over time and are dependent on perceived price, risk, access to capital, laws/regulations, and other imperfect information.

Figure IV-4 Increased Capital Costs for Increased Energy Efficiency



Investments add new devices with their own (higher) marginal efficiencies to the existing capital stock. Cumulative investments then change the average "embodied" efficiency of the stock. If there are few new investments, the average efficiency changes slowly. Large investments cause significant changes in the average efficiency. Because the existing stock is large relative to the new investments, it will always take many years before the average efficiency approaches the current marginal efficiency.

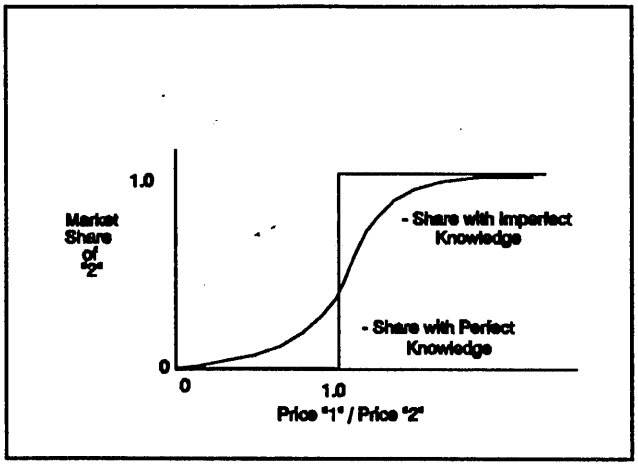
New technologies (research and development) also affect the new investment decision by increasing the efficiency of using a particular fuel. This efficiency improvement reduces fuel cost without an increase in capital costs (by the definition of technological improvement). Thus, the total cost of using a fuel is reduced, and its market share increases. The increased market share may eventually increase demand, despite the efficiency improvement.

There are both substitutable and non-substitutable uses of energy. A substitutable use is one for which any fuel is satisfactory (e.g., heating uses). A non-substitutable use is one for which only electricity is satisfactory. For instance, the computer used to print this text has a non-substitutable energy requirement.

For substitutable uses, the consumer must choose a specific type of fuel. The choice is based on perceptions of price. The impact of this perception process is illustrated in Figure IV-5. The fraction of the time consumers choose fuel "2" with price "P2" is the fraction of the time they perceive it is less expensive than all the alternatives. Figure IV-5 represents the uncertainty in the perceptions and choice process. The figure shows the resultant market shares if only two choices are available. More than two choices cannot be portrayed in two dimensions. It is possible, however, to think of the figure as a slice from a multidimensional system if all the costs (P@-(i)) except two are constant.

This approach to consumer choice simulation is called Discrete Choice Theory, a well-researched and accepted methodology (EPRI, 1982).

Figure IV-5 Uncertainty in the Perceptions of Choice Process



To help illustrate the meaning of Figure IV-5, assume that the choice is to buy a natural gas or electric clothes dryer. Let "P1" be the average cost of using the electric dryer and "P2" be the cost of using a gas dryer. The costs "P1" and "P2" reflect the capital, maintenance, and fuel components of owning and operating the dryer.

If electric and gas dryers have the same perceived usage cost, 50 percent of the population purchasing dryers will buy gas and 50 percent will buy electric dryers. If the cost of using electric dryers is more expensive than using gas, the market share will shift in favor of the gas dryers. Not all customers, however, will switch to gas if its average price is less. Some customers will still find a bargain on an electric dryer or simply be willing to pay a premium for an electric dryer.

The real-world energy requirement embodied in the capital stock can be changed only by new investments, retirements, or by retrofitting. The efficiency with which the capital uses an input factor (such as energy or materials) has a limit determined by technological or physical constraints. The tradeoff between efficiency and other factors (such as capital costs) is depicted in Figure IV-5. The efficiency of the new capital purchased depends on the consumer's perception of this tradeoff. For example, as fuel prices increase, the efficiency consumers choose for a new furnace is increased despite higher capital costs. The amount of the increase in efficiency depends on the perceived price increase and its relevance to the consumer's cash flow. As in the market share discussion above, this tradeoff process can be simulated in terms of consumer choice theory.

The efficiency tradeoff curves are called consumer-perception curves because they are estimated using cross-sectional (historical) data on the way consumers "really" make the tradeoff. Many policy makers are now interested in measure-by-measure or least-cost curves which use engineering calculation and discount rates to show how consumers should or could be made to respond to changing energy prices. ENERGY2020 allows the user to select either type of curve to represent the way consumers make their choices.

iv. Pollution Analysis

The ENERGY2020 model contains a simple module to determine pollution emissions. Fuel-specific energy-use in the residential, commercial, industrial, and electric utility sectors are multiplied by the appropriate sector-specific emissions coefficient (pounds of pollutant per Btu). These coefficients are based on the national data contained in AP42 (EPA, 1982). Aggregate-technology, sector-specific coefficients are used for natural gas, coal, LPG, petroleum products (distillate and residual), and wood energy uses. The pollutant emissions calculated are: sulfur oxides (SO_x), NO_x, CO_2, carbon monoxide (CO), volatile organic compounds (VOCs), and total suspended particulates (TSP) in tons per year. For this analysis, normally neglected LPG and biomass pollution needed to be properly quantified, since Vermont utilizes both fuels extensively.

v. Electric Supply

The electric utility sector of ENERGY2020 was used as an endogenous component of the modeling using the plant characteristics of generating facilities owned by Vermont utilities.

Electric generation used to serve the needs of Vermont customers may not be from plants located in Vermont. Conversely, electrical generation used to serve customers in other New England States may come from power plants residing in Vermont. This phenomenon is a consequence of the cost-efficient centralized-dispatch and cooperative generation-planning process of the New England Power Pool (NEPOOL, 1988). This study addressed the (direct) pollution emissions for which Vermont is responsible, no matter where the pollutants were emitted. No attempt was made, however, to calculate indirect pollution, such as emissions from refineries that deliver oil to Vermont or volatile-chemical emissions from Vermont industries using liquid/gaseous fuels as a feedstock.

vi. Other Fuel Supply

DOE primary fuel-cost data was used throughout this analysis. The base case assumes the DOE base case fuel-cost projections.

vii. Least-Cost Planning

For the purposes of this study, avoided gas costs are set to the average gas price. Conservation program costs are assumed to be capitalized by the utilities with no direct cost to the customer, although adding the conservation costs to the rate base can cause the price of the respective energy to increase. While the fully implemented ENERGY2020 model has the ability to simulate DSM program financing, the capitalization process had to be approximated here by assuming that conservation expenses stabilized to an approximately constant annual amount which could be converted to an annuity earning the rate base return.

The model simulates how customers will respond to these conservation programs. In general, these programs have increased energy efficiency and the concomitant reduced cost of using a particular fuel. That fuel then looks more attractive and receives a larger marginal market share. The increased energy price from conservation expenses, however, partially negates the cost advantage caused by improved efficiency and subsidies/rebates.

The DSM programs, as simulated, focus on the new marginal and fuel-conversion investments identified as the highest priority concern in Docket 5270 as "lost-opportunities."